2015 Washington State Ambient Air Monitoring Network Assessment

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Executive Summary

This document describes the Washington State Department of Ecology's (Ecology) 2015 Washington State Ambient Air Monitoring Network Assessment. On October 17, 2006 the U.S Environmental Protection Agency (EPA) amended its ambient air monitoring regulations. This amendment requires states to conduct detailed assessments of their air monitoring networks every five years. This is the second assessment of the Washington network under this requirement.

Purpose of the Assessment

Ecology's policy goal is to *characterize the health consequences of air pollution in Washington***.** Ecology evaluated the effectiveness and efficiency of the Washington State monitoring network in relation to this goal. This assessment ensures Ecology and its partners have the information needed to protect human health and the environment for current and future generations in Washington.

The Washington State Network

Most of Washington's monitoring network is dedicated to characterizing the two pollutants that have been shown to pose the greatest risk to public health: fine particulate matter ($PM_{2.5}$) and ozone. The remainder of the network is made up of monitors that measure larger particles (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), reactive oxides of nitrogen (NO_Y), fine particle chemical composition, air toxics, and meteorological parameters.
As of December 31, 2014, Ecology and its partners operated a network of 110 monitors at 68 monitoring stations as part of Washington's official ambient air monitoring network. The data from these monitors serve a variety of needs. The data are used to:

- Determine if air quality is meeting federal standards.
- Provide near-real-time air quality information for the protection of public health.
- Forecast air quality.
- Make daily burn decisions and curtailment calls.
- Assist with permitting activities.
- Evaluate the effectiveness of air pollution control programs.
- Evaluate the effects of air pollution on public health.
- Determine air quality trends.
- Identify and develop responsible and cost-effective pollution control strategies.
- Evaluate air quality models.

Assessment

To relate the value of its monitoring activities to the policy goal, Ecology evaluated the state network on a pollutant-by-pollutant basis. Ecology generally conducted its assessment in accordance with EPA guidance, though other analyses and tools were also used.

Findings and Recommendations

Overall, the Washington State network is efficient and effective at meeting the monitoring policy goal and objectives. Wholesale network changes are not necessary. Several specific, targeted changes will improve overall network effectiveness.

Any resource savings achieved through improvements in network efficiency should be reinvested to address monitoring gaps and high priority future monitoring requirements.

CO:

Discontinue Spokane-3rd St. S. station – While this is a Maintenance Plan/SIP-required site, the data from this monitor is well below the NAAQS, is of little value, and resources could best be used for higher priority monitoring.

PM_{10}:

Discontinue Yakima-4th Ave. monitor – While this is a Maintenance Plan/SIP-required site, the data from this monitor is well below the NAAQS, is of little value, and resources could best be used for higher priority monitoring. A proxy correlation based on $PM_{2.5}$ data, is proposed.

$PM_{2.5}$:

Discontinue nephelometer monitoring at the following sites:

- **Tulalip** - This airshed is sufficiently represented by the Marysville monitor.
- **Oakville** - The Chehalis monitor serves as a conservative proxy for $PM_{2.5}$ monitoring in Oakville.

Replace compliance monitors with FEM BAMs at key monitoring sites:

- **Spokane-Augusta Ave.** - Replace the FRM and FEM TEOM with a FEM BAM.
- **Yakima-4th Ave.** - Replace the FEM TEOM with a FEM BAM. The FRM should be retained to meet collocation requirements for FEM BAMs.
- **Vancouver-NE 84th Ave.** - Replace the FEM TEOM with a FEM BAM.

Ozone:

Investigate sources of ozone precursors in Kennewick.

Discontinue ozone monitoring at Spokane Augusta – This site is well represented by the Cheney and Spokane Greenbluff sites.

Trace Level Gasses:

Discontinue monitoring of Trace-level NO_y at Seattle Beacon Hill.

40 CFR 58, Appendix D, Section 4.3 requires Washington to operate three NO_2 samplers (two "Near-Road" and one "Area-Wide"). After a review of the data, we have found the NO_x and NO_y results to be essentially identical. The magnitude of summertime NO_z at Beacon Hill is extremely small (less than 3

ppb) and falls well within the measured sampler bias of ±5.7%, (±3 ppb). In addition, the results do not indicate a deviation between the NO_y and NO_x analyzers during periods of elevated O_3.

Given the clear redundancy of the NO_y and NO_x samplers at the Beacon Hill site, the State requests a waiver for the NO_y sampling requirement at Beacon Hill.

Meteorological:

Install meteorological monitoring at the Yakima $PM_{2.5}$ site.

Prioritize implementation of new federal monitoring requirements.

Forthcoming requirements include those associated with the EPA rule revisions for $NO_2$and potential new requirements for ozone, SO_2, and lead that EPA is reviewing over the next five years.

Introduction

On October 17, 2006, EPA amended its ambient air monitoring regulations. This amendment requires states to conduct detailed assessments of their monitoring networks every five years. The purpose of the 5-year assessment is to evaluate the effectiveness and efficiency of monitoring networks in accordance with stated monitoring objectives and goals. The second 5-year assessment, covering 2010 – 2014, is due on July 1, 2015.

To meet the ongoing requirement, Ecology assembled a team to assess and evaluate the Washington State ambient air quality monitoring network. The team is comprised of Ecology staff with expertise in the following areas:

- Monitoring
- Quality assurance
- Modeling
- Planning
- Smoke management
- Permitting

To the extent that it was practical and helpful, this assessment was conducted in general accordance with EPA guidance on monitoring network assessments. However, Ecology deviated from EPA guidance when more robust analysis methodology was available.

This document is intended to provide decision-makers with the information needed to maximize the effectiveness of Washington's ambient air monitoring network and serve as a guide for future network changes. In addition, the Recommendations section of this document identifies opportunities for overall improved network efficacy through specific, targeted reductions in monitoring activities as well as the identification of gaps in monitoring where new stations or monitors are needed. To the extent possible, any resource-savings achieved through these targeted monitoring reductions should be leveraged to address emergent monitoring needs such as the gaps in coverage identified in this document.

Ecology Policy Goal and Objectives

Ecology evaluated the effectiveness and efficiency of the Washington State monitoring network in accordance with its policy goal and objectives for ambient air monitoring. Ecology's policy goal and its objectives for air monitoring are as follows:

Goal: Characterize the Health Consequences of Air Pollution in Washington

Monitoring objectives:

- Collect only credible data that has the greatest opportunities to benefit public health.
- Increase public understanding of the health effects and costs of air pollution in Washington.
- Focus monitoring where the information is critical to protect or assess public health consequences of air pollution.
- Select continuous method monitoring over filter-based monitoring methods.
- Conserve limited financial and staff resources by using only one continuous method for each pollutant.
- Continue FEM and/or FRM filter-based monitoring only at sites where projections show that future concentrations will be higher than 80 percent of the NAAQS or will exceed Air Quality Program (AQP) health goals and/or where exceedances have been seen in the last two years.

The Washington State Network

As of December 31, 2014, the official Washington State ambient air monitoring network consisted of 110 monitors at 68 monitoring stations. The network is funded, operated, and maintained by a diverse group of entities with a vested interest in ensuring healthy air for present and future generations of Washingtonians.

Table 1 shows the Washington network partners. It should be noted that there are other entities within Washington State that monitor ambient air quality. However, for reasons discussed in detail in the Analyses section of this document, only official Washington State network monitors were evaluated for the purpose of this assessment.

Table 1. Washington State Ambient Air Monitoring Network Partners

Local Clean Air Agencies	Tribal Nations	Federal Agencies	State Agency
Benton Clean Air Agency	Makah Nation	Dept. of Agriculture Forest Service	Dept. of Ecology
Northwest Clean Air Agency	Quinault Indian Nation	Dept. of Interior Park Service	
Olympic Region Clean Air Agency	Spokane Tribe of Indians	Environmental Protection Agency	
Puget Sound Clean Air Agency	Tulalip Tribe		
Southwest Clean Air Agency	Chehalis Tribe		
Spokane Region Clean Air Agency	Yakama Nation		
Yakima Regional Clean Air Agency			

As stated previously, public health protection is the primary policy driver for the Washington State monitoring network. The network is therefore heavily weighted toward monitoring the pollutants that are known to pose the greatest threat to public health; $PM_{2.5}$ and ozone.

Ecology and its partners operate a variety of instruments as part of this network. The majority of monitors fall into two categories:

- ***Continuous monitors*** – "near-real-time" monitors that provide hourly or finer resolution data
- ***Daily filter-based samplers*** – samplers that run for 24 hours (midnight to midnight) on an EPA-defined schedule that varies from:
    - Every day (1/1)
    - Every third day (1/3)
    - Every sixth day (1/6)
    - Every twelfth day (1/12)

Table 2 presents a breakdown of the Washington State monitoring network by monitored parameter as of December 31, 2014.

Table 2. Number of Monitoring Locations by Monitor Type

Monitored Parameter	Number of Monitoring Locations	Monitor Type (continuous or daily (frequencies vary))
$PM_{2.5}$	55	55 continuous (4 of which also equipped with FRM)
Ozone	13	Continuous (2 year-round and 11 seasonal stations)
Meteorological (PSD-quality wind speed, wind direction, and ambient temperature)	15	Continuous
Chemical Speciation	4	Daily
PM_{10}	4	3 continuous + 1 Daily
Nephelometer (without $PM_{2.5}$ correlation)	2	Continuous
CO/CO Trace Gas	1/3	Continuous
Trace Gas (NO_Y, SO_2)	2	Continuous
Air toxics	1	Daily

The data from the Washington State monitoring network serves a variety of needs. Among other things, it is used to:

- Determine if air quality is meeting federal standards.
- Provide near-real-time air quality information for the protection of public health.
- Forecast air quality.

- Make daily burn decisions and curtailment calls.
- Assist with permitting activities.
- Evaluate the effectiveness of air pollution control programs.
- Evaluate the effects of air pollution on public health.
- Determine air quality trends.
- Identify and develop responsible and cost-effective pollution control strategies.
- Evaluate air quality models.

Climate, Topography, and Sources

The location of the state of Washington on the windward coast in mid-latitudes is such that the climatic elements combine to produce a predominantly marine-type climate west of the Cascade Mountains, while east of the Cascades, the climate possesses both continental and marine characteristics. Considering its northerly latitude, 46° to 49°, Washington's climate is mild (DRI, 2008).

There are several climatic controls which have a definite influence on the climate, namely: (a) terrain, (b) the Pacific Ocean, and (c) semi-permanent high and low pressure regions located over the North Pacific Ocean. The effects of these various controls combine to produce entirely different conditions within short distances.

The Cascade Mountains, 90 to 125 miles inland and 4,000 to 10,000 feet in elevation, are a topographic and climatic barrier separating the state into eastern and western Washington. The wet season begins in October, reaches a peak in winter, and then gradually decreases in the spring. High peaks in the Cascades are snowcapped throughout the year. The Columbia River, draining approximately 259,000 square miles in the Pacific Northwest and second only to the Mississippi River in volume flow, enters near the northeastern corner of the state and flows in a semi-circular pattern through eastern Washington. Before reaching the Pacific Ocean, it drains all of eastern Washington and the western slope of the Cascade Mountains between Mt. Rainier and the Oregon border.

Reservoirs on the windward slopes of the mountains provide an abundance of water for metropolitan areas, and hydroelectric projects have been developed along several rivers. Hydroelectricity supplies about 60 percent of Washington's electricity requirements.
The mountainous areas over the entire state and a major portion of the lowlands west of the Cascades are covered by timber, ranging from large Douglas fir, spruce, hemlock and cedar, a dense undergrowth of fern and moss in the rainforest on the Olympic Peninsula, to open stands of Ponderosa pine in eastern Washington. Logging and other forest management practices are major activities in these areas.

The Washington State Department of Natural Resources regulates silvicultural burning, while Ecology and the local air agencies regulate agricultural and other outdoor burning.

Western Washington: West of the Cascade Mountains, summers are cool and comparatively dry and winters are mild, wet, and cloudy. Snowfall is light in the lower elevations and heavy in the mountains in the interior valleys, measurable rainfall is recorded on 150 days each year and on

190 days in the mountains and along the coast. During July and August, the driest months, it is not unusual for two to four weeks to pass with only a few showers; however, in November and December, the wettest months, precipitation is frequently recorded on over 20 days each month. The highest summer and lowest winter temperatures are usually recorded during periods of easterly winds. Agriculture is confined to the river valleys and well-drained areas in the lowlands.

Although the Cascade Range divides the state into two major climatic regions, there are several climatic areas within each of these regions. Figures 1 and 2 present a terrain map of Washington overlaid with climatic zones (based on annual rainfall received) and locations of most network monitors. The salient zones 1-5 are described below.

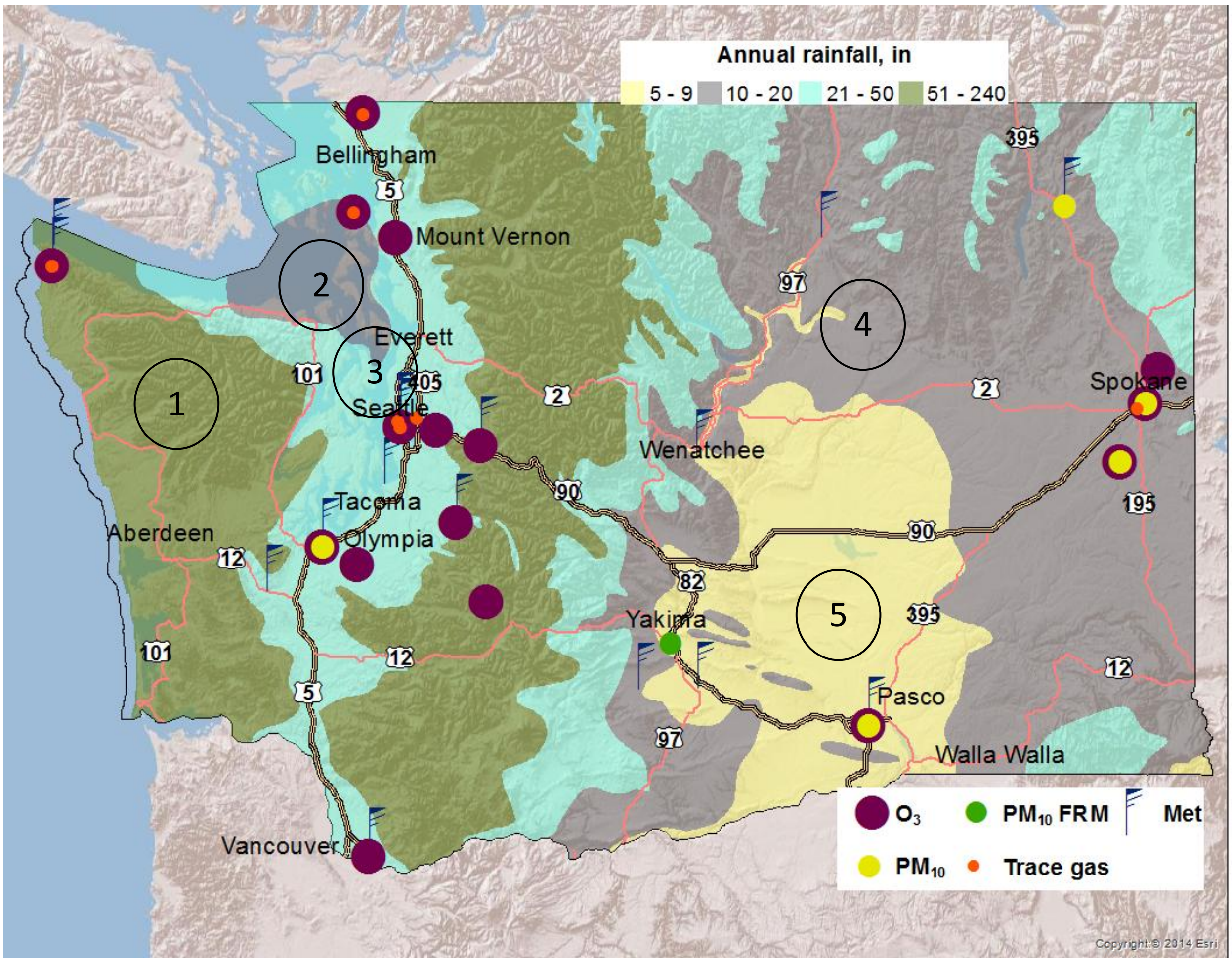


Figure 1. Washington State climatic zones and some network monitors

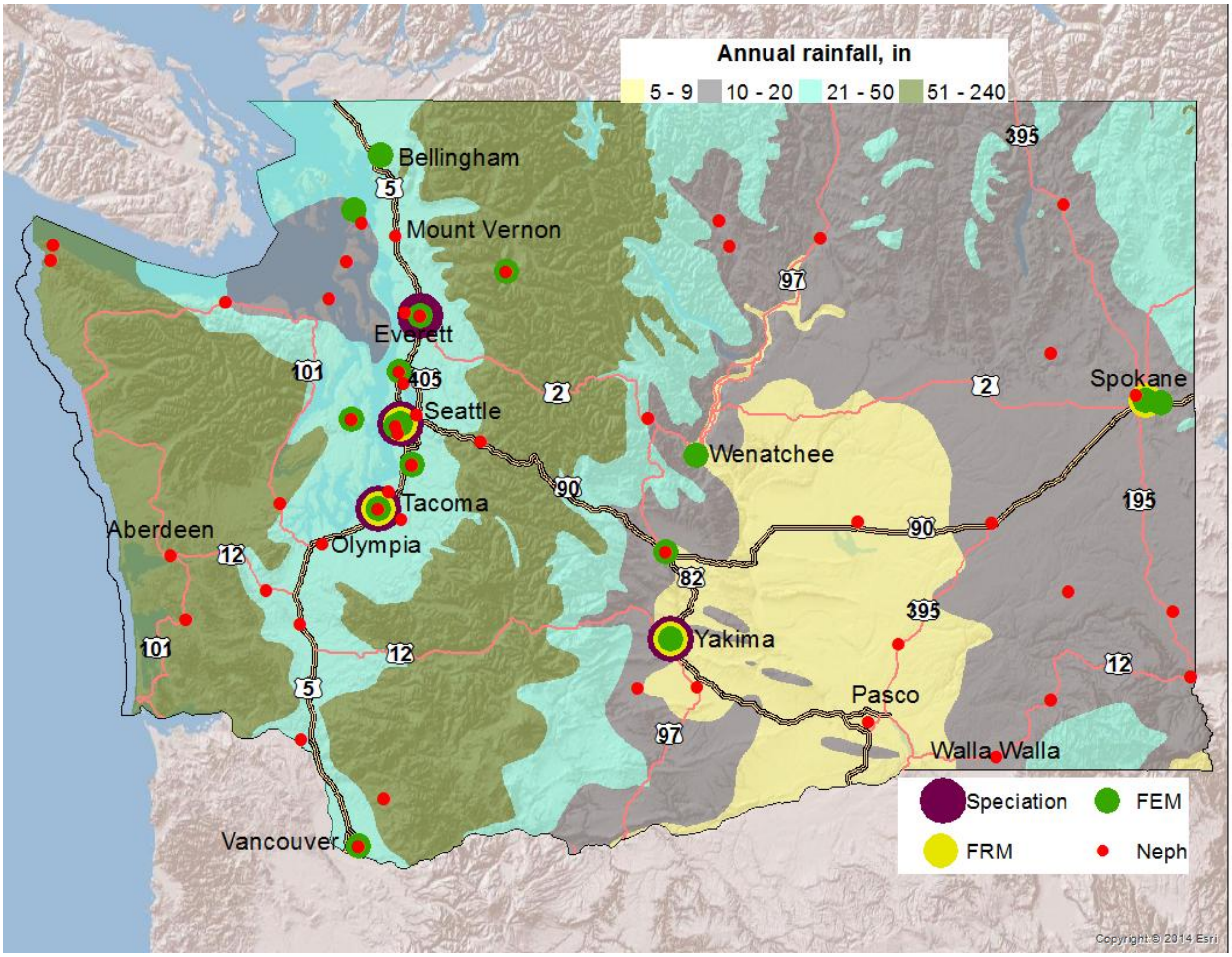


Figure 2. Washington State climatic zones and some network monitors (cont'd)

1. **The West Olympic coastal area** receives the full force of storms moving inland from over the ocean, thus heavy precipitation and winds of gale force occur frequently during the winter season. The "rainforest" area along the southwestern and western slopes of the Olympic Mountains receives the heaviest precipitation in the continental United States, with annual precipitation exceeding 150 inches along the windward slopes.
   Air pollution sources in this sparsely populated area include a few industries, outdoor/silvicultural burning, and smoke from woodstoves and other home heating devices in some communities.

2. **The northeast Olympic- San Juan Islands area** is shielded from winter storms moving inland from the ocean by the Olympic Mountains and the extension of the Coastal Range on Vancouver Island. This belt in the "rain shadow" of the Olympic Mountains is the driest area in western Washington. The coldest weather is usually associated with outflows of cold air from the interior of Canada.

The few air quality concerns in the area are mostly caused by smoke from wood stoves and other home heating devices in larger communities, outdoor burning, and by some industrial facilities.

3. **The Puget Sound Lowlands** includes a narrow strip of land along the west side of Puget Sound, extending southward from the Canadian border to the Centralia area. Variations in the temperature, length of the growing season, fog, rainfall, and snowfall are due to such factors as distance from the Sound, the rolling terrain, and influx of air from the ocean through the Strait of Juan de Fuca and the Chehalis River valley. Most of this area is near the eastern edge of the rain shadow of the Olympic Mountains. The prevailing wind direction is south or southwest during the wet season and northwest in summer.

   This is the most densely populated and industrialized area in the state. Vehicular, industrial, domestic, and marine sources (shipping, ferries) and both vessels and traffic at ports are among the main anthropogenic sources in the area. Summertime $PM_{2.5}$ concentrations are usually low due to sufficient atmospheric mixing, but $PM_{2.5}$ can be elevated under conditions of clear skies, light wind and a sharp temperature inversion during the home heating season (October–March) when woodstoves and other heating devices are typically used. Some sheltered valleys (such as Darrington, Kent, and Duwamish) can experience a buildup of pollutants even when most other areas are moderately ventilated. Some areas with a high density of woodstove use (South Tacoma, Marysville, Lynnwood, Darrington, and Bremerton) frequently experience rapid rises of $PM_{2.5}$ levels in the home heating season, during periods of poor dispersion. Emissions of ozone precursors in industrial and populated areas can result in elevated ozone levels downwind on hot summer days characterized by low-to-moderate northerly/easterly winds.

   Eastern Washington: This section of the state is part of the large inland basin between the Cascade and Rocky Mountains. East of the Cascades, summers are warmer, winters are colder, and precipitation is less than in western Washington. The major agricultural areas are in eastern Washington.

   During most of the year, the prevailing direction of the wind is from the southwest or west. The frequency of northeasterly winds is greatest in the fall and winter. Melting of the snow provides irrigation water for orchards and other agricultural areas in the Okanogan, Wenatchee, Methow, Yakima, and Columbia River valleys. Dry land farming practices are generally followed in the small-grain growing areas.

4. **The Okanogan-Big Bend** area includes fruit-producing valleys along the Okanogan, Methow, and Columbia rivers, grazing land along the southern Okanogan highlands, the Waterville Plateau, and part of the channeled scablands. Major air pollution sources are outdoor burning (year round, except during summer fire safety burn bans), agricultural burning (spring and fall burn seasons), orchard heaters, smudge pots, silvicultural burning, and wintertime woodstove use. In rare instances, smoke from some burns may become entrained in evening downslope flow and settle in sheltered valleys (examples include Wenatchee, Twisp, Winthrop, Omak, and Leavenworth). Smoke from any combination of

these sources, if coupled with a strong temperature inversion and calm conditions, often result in elevated $PM_{2.5}$ concentrations.

5. **The Central Basin** includes the Ellensburg valley, the central plains area in the Columbia Basin south from the Waterville Plateau to the Oregon border and east to near the Palouse River. This is the lowest and driest section in eastern Washington.

   Wheat and barley are the most widely grown crops in this area, while alfalfa, lentils, and potatoes are also grown on a smaller scale. Agricultural and outdoor burns are the main $PM_{2.5}$ sources. Except for the Tri Cities, Ellensburg, Yakima and Walla Walla, smoke from home heating devices and prescribed burning is not a major concern in this sparsely populated area. Tilling operations, windblown dust, and re-suspended road dust sometimes give rise to elevated levels of PM_{10}.

Air Quality Monitoring in Washington State (Past and Present)

This section describes air quality monitoring in Washington and provides background information that helps to explain the current network.

Carbon Monoxide

CO sampling has been conducted in Washington since the 1960s. Since 1970, when the federal Clean Air Act first mandated motor vehicle emission controls, tailpipe emissions of CO, hydrocarbons, and oxides of nitrogen have decreased. As air quality improved, the CO monitoring network was downsized. Today, there is only one remaining CO station, Spokane-3rd St. S. In 2014, this station measured a maximum 8-hour value of 1.7 ppm.

Nitrogen Dioxide

NO_2 sampling in Washington started in 1975. NO_2 monitoring was discontinued in 1987 and re-established in 1995 at Seattle-Beacon Hill. During the 1990s, several NO_2 studies were conducted to determine concentrations at potential hot spots and evaluate downwind photochemistry. The results from these studies revealed concentrations well below the NAAQS in effect at the time.

In 2007, the existing NO_2 monitor at Seattle-Beacon Hill was replaced with a high sensitivity sampler measuring reactive oxides of nitrogen (NO_Y = Nitric Oxide (NO) + NO_2 + other oxidized nitrogen species), as required by the station's present classification as an NCore station. NO_Y minus NO is a good approximation of NO_2 at this location. NO_Y is also monitored at the Cheeka Peak station, which is a rural background site located in the northwestern-most corner of the state. NO_2 levels at these two stations are well below the new NAAQS established on February 9, 2010. Near-road NO_2 monitoring was established in Seattle in March of 2014.

Ozone

Ozone monitoring started in 1972 at a single station in Spokane. Though ozone has been monitored at over 50 different stations throughout the state, many of these were exploratory in nature and only operated for a year or two. On average there have been about 10 to 12 ozone stations operating during the ozone season (May to September).

Sulfur Dioxide

In the early 1970s, there were as many as 28 SO_2 monitoring stations located throughout the State. Since then, emissions reductions were realized as: (a) source control measures were implemented, (b) many of the larger SO_2 sources shut-down, and (c) during the last decade gasoline and diesel fuel sulfur content was cut by nearly 90 percent.

As air quality improved and pollution levels dropped well below the NAAQS, SO_2 monitoring for compliance with the federal standards was discontinued. Currently, there are three trace-level SO_2 monitors in the Washington State network at the Seattle-Beacon Hill, Cheeka Peak, and Anacortes stations. The Seattle-Beacon Hill NCore station measures values representative of the overall region and Cheeka Peak provides background and long-range transport data. The Anacortes SO_2 monitor lies upwind of the March Point refineries.

Particulate Matter

Particulate Matter (PM) monitoring in the form of gross particle fallout and Total Suspended Particulate (TSP), PM with a nominal size of 25-to-45 µm started in the 1960s. PM presented a considerable air quality problem. By 1971 the State had over 100 TSP sampling stations. Several of these exceeded the primary or the secondary NAAQS for TSP. In the early 1980s, scientific research was emphasizing the adverse health effects of smaller particles. As a result, Ecology began PM_{10} sampling at 24 stations across the state in 1985. Many of the new PM_{10} monitoring stations exceeded the PM_{10} NAAQS when it was promulgated in 1987. EPA rescinded the TSP NAAQS in recognition of the new health-based PM_{10} NAAQS, and TSP sampling was phased out by 1996. EPA revoked the annual PM_{10} standard in 2006 due to a lack of evidence linking PM_{10} to chronic health problems but retained the 24-hour standard to address acute health impacts. PM_{10} is still monitored at Colville, Kennewick, Spokane, and Yakima.

Fine Particulate Matter

In 1997 EPA issued a new PM standard for particles with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$). The new $PM_{2.5}$ NAAQS were based on human population exposure and laboratory studies that demonstrated the harmful effects of finer particles. In 2006 EPA revised the 24-hour $PM_{2.5}$ NAAQS to 35 $\mu g/m^3$. In 2012 EPA revised the annual standard from 15 to 12 $\mu g/m^3$.

Ecology and its partners currently operate an extensive $PM_{2.5}$ monitoring network comprised of continuous monitors and FRMs at stations throughout Washington. FRMs are filter-based instruments that provide a 24-hour sample while the continuous network provides hourly data.

The continuous network represents Ecology's single largest ongoing resource investment for any pollutant and provides near-real-time data for a variety of users with a diverse array of data needs and applications. A primary driver for the use of the continuous monitors is public health protection through the use of the near-real-time data.

Lead

Lead monitoring began in 1979. Due to the phase out of leaded gasoline and the regulation of industries that produced lead, concentrations dropped drastically since the mid-1980s. By 1996 lead monitoring was being conducted only at one station in Seattle. The values from this last station were less than half the NAAQS. Consequently, lead monitoring under the 1978 standard was discontinued in 1997.

In 2008, EPA strengthened the lead standard by reducing it from 1.5 $\mu g/m^3$ to 0.15 $\mu g/m^3$. In the 2010 monitoring rule, EPA lowered the threshold required for establishing monitors to 0.5 tons per year (tpy) near industrial sources of lead. EPA also limited non-source-oriented monitors to NCore sites, rather than require monitoring in every core based statistical area (CBSA) with a population over 500,000. The 2010 monitoring rule also required that monitors be deployed at selected airports, including two in Washington. Lead monitoring was conducted at Auburn Municipal Airport and Harvey Field Airport from December 2011 to December 2012, since neither site registered a 3-month rolling average in excess of 50 percent of the NAAQS, the monitoring at both airports was concluded in December 2012 (US EPA, 2013).

Lead is currently monitored at the Seattle-Beacon Hill station as part of the National Air Toxics Trends Station (NATTS) and Chemical Speciation Network (CSN) programs. EPA Region 10 has agreed this monitoring work satisfies the relevant CFR requirements.

Chemical Speciation Network

There are currently four CSN stations in Washington State. They include one EPA-designated CSN monitoring station (Seattle-Beacon Hill) and four supplemental stations. Washington State CSN stations are shown in Table 3.

Table 3. $PM_{2.5}$ CSN Sites in Washington State

Site	Estimated 2014 $PM_{2.5}$ FRM 24 Hour Design Value, $\mu g/m^3$	CSN Sampling Started
Seattle-Beacon Hill	16	February 2000
Tacoma-L St.	31	January 2006
Vancouver	30	June 2008
Yakima-4th Ave.	33	November 2007
Seattle 10th & Weller	N/A	March 2015

Seattle-Beacon Hill operates on an every third day (1/3) schedule. In addition to the filter-based sampler, an automated semi-continuous organic and elemental carbon sampler is also operated at this station. The other supplemental stations run on an every sixth day (1/6) schedule.

Historical Speciation Stations – Supplemental speciation was previously conducted on a 1/6 schedule at the following stations:

- **Seattle-Georgetown** – From 4/2000 to 10/2004
- **Lake Forest Park-Town Center –** From 10/2001 to 12/2005
- **Seattle-Maple Leaf Reservoir –** From 8/2001 to 12/2002
- **Seattle-Olive St. –** From 1/2003 to 9/2007
- **Seattle-Duwamish** – From 6/2002 to 12/2007
- **Spokane-Ferry St**. **–** From 1/2005 to 1/2009
- **Vancouver- 4th Plain Blvd. -** from 6/2008 to 10/2014
- **Marysville – 7th Ave.** – from 3/2009 to 3/2015

*The Vancouver 4th Plain speciation site was discontinued as result of an EPA analysis driven by budget cuts.

Several source apportionment studies have been conducted with CSN data from historical and current sites (Wu et al., 2006; Hopke et al., 2006; Naeher et al., 2007; Kim and Hopke, 2008; Ecology, 2010).

Air Toxics Monitoring

As part of the National Air Toxics Monitoring Pilot Program, Ecology received an EPA grant to conduct an extensive air toxics study in the Seattle area. Air toxics sampling for VOCs, carbonyls, metals, Polycyclic Aromatic Hydrocarbons (PAH), and Semi Volatile Organic Compounds (SVOCs) was conducted at six sites between 2000 and 2002. The study successfully characterized ambient air toxics concentrations, and the results were used to evaluate modeling results, and determine health risks in the Seattle area.

After the pilot study, the Seattle-Beacon Hill station became a NATTS. The primary purpose of the NATTS network is to track trends in ambient air toxics levels to facilitate measuring progress toward emission and risk reduction goals. Long-term goals of NATTS sampling include assessing the effectiveness of emission reduction activities and evaluating and subsequently improving air toxics emission inventories and model performance. The NATTS program provides for long-term sampling of VOC, carbonyl, PM_{10} metals, hexavalent chromium*, PAH, and SVOC at the Beacon Hill NATTS.

*Hexavalent chromium was discontinued as a parameter nationally by EPA in 2014.

Air toxics have been sampled at the Seattle-Beacon Hill station since January 13, 2000.

Meteorological Monitoring

Ecology and its partners currently operate a network of 15 Prevention of Significant Deterioration (PSD)-quality meteorological stations equipped with a wind vane and anemometer. These stations serve permitting, air quality forecasting, and burn management program needs. They are located as follows:

Table 4. Network Meteorological Stations

Station Name	Date Established
Seattle-Beacon Hill	1/1979
Tacoma-Tower Dr.	1/1991
North Bend-North Bend Way	1/2000
Enumclaw-Mud Mtn.	2/2004
Cheeka Peak	5/2006
Vancouver-Blairmont Dr.	12/2007
Toppenish	6/2009
Spokane-Augusta Ave.	7/2009*
Oakville	10/2009
White Swan	11/2009
Omak	10/2010
Colville	3/2011
Kennewick	8/2012
Wenatchee	11/2012
Seattle 10th & Weller	4/2014

*Initially operated at Ferry St. ~1 mile away, from 8/1/2001 to 3/24/2009.

Temporary Monitors

Temporary monitors can provide a cost-effective supplement or alternative to more permanent monitoring stations. They allow for relatively quick response to emergent air quality issues, such as monitoring smoke from wildfires or monitoring in areas with persistent public air quality complaints. They also represent a less costly approach to characterizing air quality in air sheds where air quality is unknown.

Ecology employs two types of temporary monitors for these purposes:

- Mobile monitors - trailers equipped with nephelometers
- Portable monitors - no shelter (monitors must be transported and housed)

Ecology currently uses these monitors for $PM_{2.5}$ and ozone monitoring throughout the state.

Mobile Monitors

Ecology has three mobile monitors that are used primarily to characterize air quality in air sheds where air quality is unknown, but air pollution problems are suspected based on complaints and other information. Each mobile monitor consists of a nephelometer housed in a trailer that can be hitched to a vehicle. They are therefore relatively quickly and easily deployed and are generally used for short-term monitoring. Although nephelometers do not report absolute $PM_{2.5}$ concentrations, they do report measurements of light-scattering by fine particles as backscatter (bscat). For particles with similar optical properties, the amount of scattering is proportional to the particle concentration. Analysis of bscat data from the mobile monitors may therefore be used as a qualitative indicator of possible $PM_{2.5}$ problems, and help track day-to-day trends.

Portable Monitors

Ecology currently uses two portable, non-Federal Reference Method (non-FRM), Environmentally-Protected Beta Attenuation Monitors (EBAMs) and four portable, non-Federal Reference Method (non-FRM), E-Samplers. These monitors are used to investigate smoke complaints, verify modeled hot spots, monitor smoke from wildfires or other fires, and identify additional monitoring needs throughout the state. In addition, Ecology has two portable FEM ozone monitors. These monitors are used to verify modeled hot spots, track ozone plumes, verify that the current ozone network is adequate and sited properly, and better understand ozone transport issues.

Ecology has also conducted active mobile monitoring using nephelometers and ozone analyzers operated in a moving vehicle. The monitoring instrument is housed inside the vehicle, and the inlet draws ambient air through a window while the vehicle drives through neighborhoods of interest. This tool is useful in mapping the gradient of $PM_{2.5}$ and/or ozone pollution across neighborhoods and cities, investigating the breadth of pollution hotspots, and evaluating how well existing monitoring sites represent whole neighborhoods. Between 2010 and 2014, Ecology conducted mobile monitoring evaluations in Vancouver, Goldendale, Quincy, Suncrest, and Ellensburg ($PM_{2.5}$); and Bremerton, Brinnon, and Kennewick (ozone).

During the 2010 network assessment, a modeled ozone hotspot was seen in the northeast corner of the Olympic Mountains. While the theoretical reasons for O_3 accumulation here are understandable (east winds that traverse O_3 precursor source areas and then dam up against the Olympics), Ecology attempted to verify this phenomenon by placing two portable monitors in Brinnon and Bremerton, in the summer of 2010. Neither monitor recorded high ozone levels and interestingly, the model did not predict an ozone hotspot in the area thereafter.

When air quality forecasts at a 4 km resolution became available, the AIRPACT-4 model often predicted an ozone hotspot around Kennewick. A portable ozone sampler was deployed for two successive summers and the presence of elevated ozone levels confirmed. A permanent ozone monitor will commence operations in summer 2015.

Air Monitoring – The Next Five Years

This section provides an overview of the recently proposed and final rules as well as the upcoming NAAQS reviews anticipated in the next five years—2015 to 2020—for the six criteria pollutants. The previous monitoring network assessment reviewed ambient air quality monitoring in Washington as of the end of 2014.

Proposed and Final Rules Affecting Ambient Monitoring

The following table describes actions EPA has proposed or finalized since the last assessment that will impact ambient air quality monitoring in Washington—and the rest of the country—over the next five years. For an update of current standards, visit the National Ambient Air Quality Standards page at EPA's website.

Table 5. Final and Proposed EPA Actions, Standards		
Pollutant	**Most Recent Action**	**Standard**
Final Rules		
Carbon Monoxide (CO)	August 31, 2011 CO standard retained without change, but CO required to be included in near-road monitoring for NO_X	• 9 ppm, 8-hour standard • 35 ppm 1-hour standard–not to be exceeded more than once a year.
Particulate matter (PM_{10} and $PM_{2.5}$)	Dec 14, 2012 24-hour $PM_{2.5}$ and PM_{10} standards retained; annual standard changed. $PM_{2.5}$ monitoring at one near-road location became required.	• 2006 24-hour $PM_{2.5}$ standard retained at 35 µg/m^3. • Annual standard changed to 12 µg/m^3. • PM_{10} 24-hour standard of 150 µg/m^3 retained.
Sulfur Dioxide	Jun 22, 2010 Implementation delayed; could create Ecology oversight of selected source monitors if monitoring option chosen (see discussion below).	• 1-hour standard set at 75 ppb, (99th percentile of daily max)
Nitrogen Dioxide	Feb 9, 2010 Final revisions of NO_2 monitoring requirements published in 2012. NO_2 re-established at Seattle Beacon Hill in 2012. First required near-road installed in Seattle in 2014; on track for second site by Jan. 2016.	• 2010 1-hour of 100 ppb, 98th percentile of 1-hour daily maximum
Ozone (O_3)	Mar 27, 2008 Approval and finalization of the 2008 standard was delayed.	• 75 ppm, 3-year average of 4th highest 8-hour maximum
Proposed Rules		
Ozone	Proposed: Nov 25, 2014 Expected final by October 1, 2015 (court-ordered deadline)	Proposed: • Primary standard: 65 to 70 ppb, but EPA taking comment on lower levels including 60 ppb and on retaining the

Table 5. Final and Proposed EPA Actions, Standards		
Pollutant	**Most Recent Action**	**Standard**
		current standard. • Retain the current indicator, averaging time (8 hours), and form (annual fourth-highest daily maximum, averaged over 3 years. • Secondary standard the same as primary.
Lead	Proposed: January 3, 2015 To retain the lead standard without change –expect no changes to monitoring network. Reporting threshold changing starting for emission year 2014 (see discussion below). Any lead source that emits 0.5 tpy or more will be required to conduct ambient monitoring near them as per the 2010 standard.	Propose: • Retain current standard of 0.15 µg/m^3. The averaging time was revised to a rolling 3-month period with a maximum (not to be exceeded) form, evaluated over a 3-year period.

More detail on Ozone: In 2014, EPA proposed lengthening the ozone season, which currently runs from May 1st through September 30th. Past ozone monitoring in Washington State has demonstrated elevated ozone concentrations rarely occur outside of the May through September season. It is expected the ozone season will continue to be May through September in Washington when EPA's ozone proposal is finalized.

If any areas are designated nonattainment with respect to this new standard, new Photochemical Air Monitoring Stations (PAMS) monitoring will be required at NCore sites.

Lead (Pb): On December 14, 2014, EPA proposed that the 2008 Pb standard be retained without change. Ecology does not anticipate any changes to monitoring network when the standard is finalized. The comment period closed April 6, 2015. However, a change in the reporting threshold for Pb could trigger source-oriented monitoring at sources above the revised threshold. The reporting threshold for Pb was revised in the Air Emissions Reporting Rule (AERR) in February 2015. This rule requires agencies to install ambient monitors near Pb sources emitting 0.50 tpy or more by December 27, 2011.

Ongoing and Follow-up Requirements from Previously Finalized NAAQS

Nitrogen Dioxide (NO_2): Ecology has additional responsibilities to fulfill for near roadway monitoring of NO_2. NO_2, CO, $PM_{2.5}$, and meteorology are monitored at the Phase I site—Seattle 10th & Weller established in 2014. The Phase II site in Tacoma measuring NO2 and meteorological data is expected to be operational by January 2016.

Sulfur Dioxide (SO_2): The 1-hour standard for SO_2 was finalized in 2010, but implementation of the standard was delayed. Implementation of this standard could possibly result in monitoring requirements near larger SO_2 sources or clusters of sources that have the potential to violate the standard. The proposed Data Requirements Rule (DRR)—due to be finalized in August 2015—will provide more information for evaluating levels around SO_2 sources in Washington.

As part of the proposed DRR, states must submit a list of sources around which ambient levels of SO_2 will be evaluated by January 15, 2016. The list must identify whether monitoring or modeling will be used for each source or areas with clusters of sources. If monitoring is selected, the monitoring protocol for those sources or areas is due by July 1, 2016, as part of the Annual Network Plan. Monitors must be operational by January 1, 2017.

Should the monitoring approach be selected for any source or area with multiple sources, it would trigger an ambitious timeline for identifying monitoring locations, securing sites, purchasing and testing equipment, with a significant staff and resource long-term commitment. Ecology's technical team is charged with evaluating sources and potential monitoring and modeling approaches to determining compliance. The technical team will present its recommendations to the Air Quality Program Leadership Team shortly after the DRR is finalized in August 2015. If monitoring is selected, staff will be researching opportunities to minimize the burden on resources associated with establishing and maintaining monitoring sites by exploring potential partnerships with local clean air authorities and affected sources.

Ongoing National Ambient Air Quality Standards Reviews

The Federal Clean Air Act requires EPA to periodically review the NAAQS. Reviews are conducted by EPA at roughly five years intervals. Any NAAQS review completed during the next few years may result in new or revised ambient monitoring requirements. Ecology will monitor the NAAQS under review and evaluate implications of any new requirements. The review process is extensive and provides opportunities for public comment. It is briefly outlined below:

- **Planning:** The planning phase begins the NAAQS review process. EPA holds workshops, develops questions that will frame review, prepares an Integrated Review Plan (IRP) that has schedule for review and has key science issues that will guide the review.
- **Integrated Science Assessment (ISA)**: This assessment includes a comprehensive review of science, especially new information since last time the standard was reviewed and includes judgments which inform the REA.
- **Risk/Exposure Assessment (REA)**: In this phase, EPA develops quantitative characterizations of exposures and associated risks to human health or the environment based on recent air quality data and estimates.
- **Policy Assessment (PA):** EPA staff writes a policy statement to ''bridge the gap'' between the agency's scientific assessments, presented in the ISA and REA(s), and the judgments required of the EPA Administrator in determining whether it is appropriate to retain or revise the NAAQS. The PA focuses on the information most pertinent such as indicator, averaging time, form, and level.
- **CASAC review:** The Clean Air Scientific Advisory Committee (CASAC) gives advice and recommendations on the adequacy of the existing standards or revisions that may be

appropriate to consider. Scientific review during the development of these documents is thorough and extensive and includes an opportunity for public comment.

- **Rulemaking:** EPA considers information in above documents and CASAC recommendations, makes a decision, and issues a proposal, if a change is being proposed. After public comment, EPA issues final rule.

As of March 2015, the status of NAAQS reviews is as shown in **Error! Reference source not found.**.

EPA United States Environmental Protection Agency

NAAQS Reviews: Status Update

(as of March 31, 2015)

	Ozone	Lead	Primary NO_2	Primary SO_2	Secondary NO_2 and SO_2	PM	CO
Last Review Completed (final rule signed)	Mar 2008	Oct 2008	Jan 2010	Jun 2010	Mar 2012	Dec 2012	Aug 2011
Recent or Upcoming Major Milestone(s)[1]	**August 2014** Final REAs Final PA **Nov 25, 2014** Proposed rule **Oct 1, 2015**[2] Final rule	**May 2014** Final PA **Dec 2014** Proposed decision	**June 2014** Final IRP **January 2015** 2nd Draft ISA **Spring 2015** REA Planning Document	**October 2014** Final IRP **Summer 2015** 1st Draft ISA **Fall 2015** REA Planning Document	**Summer 2015** Draft IRP	**Winter 2015/2016** Draft IRP	TBD[3]

Additional information regarding current and previous NAAQS reviews is available at: http://www.epa.gov/ttn/naaqs/

[1] IRP – Integrated Review Plan; ISA – Integrated Science Assessment; REA – Risk and Exposure Assessment; PA – Policy Assessment
[2] **Bold and underlined** dates indicate court-ordered or settlement agreement deadlines
[3] TBD = to be determined

3

Figure 3 NAAQS review status as of March 2015

The above table is from a presentation given by Anna Wood, EPA Air Quality Policy Division Director, at the Westar Business meeting on March 31, 2015.

Analyses

Ecology evaluated the Washington monitoring network in accordance with its policy goals and objectives. The two pollutants of greatest concern for threats to public health in Washington are $PM_{2.5}$ and ozone. For this reason, $PM_{2.5}$ and ozone comprise the majority of monitoring activities in Washington State and are the primary focus of this assessment.

To conduct this assessment, Ecology followed EPA guidance with the addition of several supplemental analyses and tools. The $PM_{2.5}$ and ozone networks were evaluated using decision matrices. A decision matrix is a tool that synthesizes multiple criteria into a single value score for each station. The decision matrix criteria are summarized below; the full site rankings for each criteria are included Appendix A and B. Decision matrices were not constructed for other pollutants due to the limited number of monitors.

It should be noted that the topography, meteorology, and emissions in Washington, particularly western Washington, are quite heterogeneous as compared to other areas of the country, such as the Midwest. For this reason, the guidance and tools provided by EPA for identifying redundancies in monitoring were not particularly useful for Washington State. Specifically, cross-comparing stations as suggested by EPA, and calculating correlation matrices was of little utility as many stations with high R^2 values nevertheless represented unique air sheds, including those within the same metropolitan statistical areas. Instead of cross-comparing stations as suggested by EPA, Ecology compared several site pairs known to report similar values and evaluated their redundancy.

Scope of Analysis

Ecology decided to limit its analysis to the official Washington State network monitors for the following reasons:

- It is unknown whether non-network monitors are operated and maintained in accordance with established Ecology data quality requirements for quality control and quality assurance.
- Ecology has little control over the decision making processes regarding the siting, establishment, operation, relocation, or removal of non-network monitors.
- While resource-savings could be achieved by leveraging non-network monitors (i.e., turning off Ecology monitors in air sheds where a non-network monitor provides similar information), non-network monitors may be discontinued without input from Ecology and its partners. This situation could leave data users without potentially important information.

It should be noted that non-network monitors regularly provide useful data for users in areas where Ecology does not monitor. Some non-network monitor data were used to inform Ecology’s analysis of spatial pollution patterns and identification of potential gaps in monitoring.

Fine Particulate Matter Background

Washington’s $PM_{2.5}$ pollution events are relatively short in duration and are most often associated with wintertime stagnation events. Unlike in other areas of the country, secondary $PM_{2.5}$ formation during summertime, either from smog episodes or SO_2 oxidation, does not have substantial impacts on air quality. Depending on the area, $PM_{2.5}$ pollution in Washington comes mainly from smoke associated with home heating devices, agricultural burning, and non-agricultural outdoor burning. Transportation and other mobile (on- and off-road) sources are also contributors but much less than smoke in its various incarnations. In general, $PM_{2.5}$ values are highest during the home heating season (October through March) and drop off markedly during the warmer months. However, high $PM_{2.5}$ values occasionally occur at other times of year, particularly east of the Cascade Mountains, during wildfires or agricultural field stubble burning.

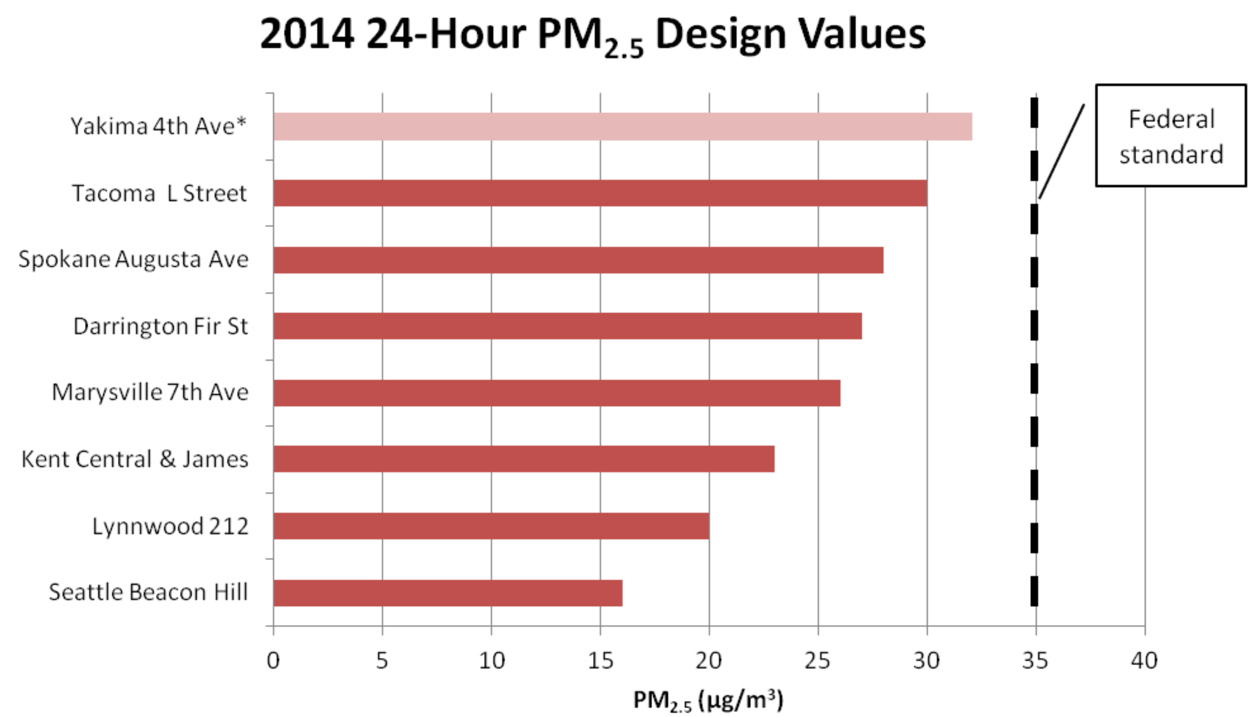
Because there is a great amount of epidemiological data associating $PM_{2.5}$ with adverse health effects, Ecology has made reducing the health threats associated with $PM_{2.5}$ a priority and has invested heavily in $PM_{2.5}$ monitoring.

Compliance Monitoring for Fine Particulate Matter

Ecology and its partners operate a statewide network of 16 compliance monitors that meet EPA requirements for comparison with the NAAQS. Four of these sites have filter-based Federal Reference Method monitors (FRMs), and all 16 have continuous Federal Equivalent Method monitors (FEMs). As of December 31, 2014, all the FEMs operating in Washington State were Thermo Scientific Tapered Element Oscillating Microbalances (TEOMs™). Ecology plans to introduce several FEM Beta Attenuation Monitors (BAMs) into its network in 2015. As BAMs are more widely used instruments nationally and generally achieve higher rates of data completeness in other states, Ecology anticipates that shifting key monitoring sites from TEOMs to BAMs will improve data completeness and reduce operational burden.

Of the 16 sites with federal reference/equivalent method monitors, only eight have been operating in their current location for the full three years necessary to compute an official design value. All sites with federally referenced monitors reported 24-hour design values below the current standard of 35 $\mu g/m^3$ in 2014.

As illustrated below in Figure 4, all annual design values fell well below the federal annual standard of 12 $\mu g/m^3$; the highest annual design value in the network of compliance monitors was 8.9 $\mu g/m^3$ at Yakima-4th Ave. At sites with FRMs, the design value is calculated using primarily FRM data, with FEM data used to fill in on days without 24-hour FRM concentrations.



* Yakima design value estimated from incomplete data.

Figure 4. 2014 24-hour $PM_{2.5}$ design values

Non-Compliance Monitoring for Fine Particulate Matter

Ecology and its partners operate an extensive network continuous nephelometers statewide to monitor estimated $PM_{2.5}$ concentrations. These nephelometers have been correlated with FRMs to produce FRM-like $PM_{2.5}$ concentrations, as per EPA guidance (US EPA, 2002).This network represents Ecology's single largest ongoing resource investment for any pollutant and provides near-real-time data for a variety of users with a diverse array of data needs and applications. Nephelometers are not FRM/FEM and the $PM_{2.5}$ data produced by nephelometers cannot be used for determining compliance with the NAAQS.

Updating Fine Particulate Matter Correlations

Ecology relies heavily on its $PM_{2.5}$-correlated nephelometers as they are much less costly to operate than FEM TEOMs and FRMs. However, aerosol composition can change over time, and most of the nephelometer-FRM correlations were established several years ago. Ecology believes it is important to prioritize the updating of its $PM_{2.5}$- nephelometer correlations as resources permit to ensure reliable estimates of $PM_{2.5}$ concentrations from this large network.

Supporting a Single Continuous Onsite Monitor

Ecology believes it is important to conserve limited financial and staff resources by using only one continuous method for each pollutant.

Fine Particulate Matter Decision Matrix

Ecology used a decision matrix to analyze the official $PM_{2.5}$ monitoring network. Stations were ranked in order of value as informed by Ecology's monitoring policy goals and objectives. The decision matrix primarily emphasized the protection of public health. As elevated $PM_{2.5}$ concentrations are associated with a number of adverse health effects, the decision matrix ascribed higher scores to sites with higher measured pollutant concentrations and large populations represented. The synthesis of measured concentrations and population represented at each site acts as a surrogate for population exposure risk.
All analyses were conducted in R 3.1.2 and ArcGIS 10.2.

Scoring

The criteria included in the $PM_{2.5}$ decision matrix are summarized in Table 6 below. They fit roughly into four categories: measurement variables, social variables, source variables, and environmental variables.

Table 6. $PM_{2.5}$ Decision Matrix Criteria

Category	Criterion	Units
Measurement	24-hour design value	µg/m^3
	Annual design value	µg/m^3
	Days over 20 µg/m^3	%
	Probability of day over 35 µg/m^3	%
	Trend	µg/m^3/year
Social	Population served	# people
	Population growth	# people/10 years
	Environmental justice index	---
Source	Point source emissions	tons
	Smoke impacts	tons/person
	Traffic density	AADT-miles
	Agricultural and non-residential outdoor burning	acres burned/total land area
Environmental	Geographic area served	square meters
	Error between AIRPACT model and monitor	%
	Forecasting value	---

The values for each criterion were normalized to a scale of 0–10, with the highest value given a 10 and the remaining values scaled linearly relative to the maximum. The final results of the decision matrix are shown in Figure 5. Sites with the highest scores are considered to provide the greatest relative value to the Washington State network.

The final rankings should be interpreted with caution. As with any summary statistic, the scores in each criterion have an implicit margin of error, and these margins of error are aggregated in the final scores. In addition, while every attempt was made to scale and synthesize the scores in the most objective manner possible, adjustments in these methods can lead to small changes in the final site rankings. Therefore, differences of <5 points in the final scores are likely not significant. It is recommended the final values be interpreted in broader quantiles rather than as specific scores. For example, a site ranked among the top ten can be assumed to provide greater value than a site ranked in the bottom ten. However, a site with 50 points cannot be assumed with confidence to be significantly more valuable than a site with 49 points.

The intention of the decision matrix analysis was to best capture the scientific value each site contributes to the state monitoring network, independent of legal requirements, funding sources, managing agencies or other non-specific factors. It should be also noted that some sites included in the decision matrix are not candidates for removal due to federal and/or state monitoring requirements. These include sites in the Agburn network (Walla Walla, Mesa, Dayton, Pullman, Ritzville, LaCrosse, Rosalia, and Moses Lake), the National Core (NCore) network (Seattle-Beacon Hill, Cheeka Peak), and the National Air Toxics Trends Stations (NATTS) network (Seattle-Beacon Hill). Sites were evaluated irrespective of these limitations.

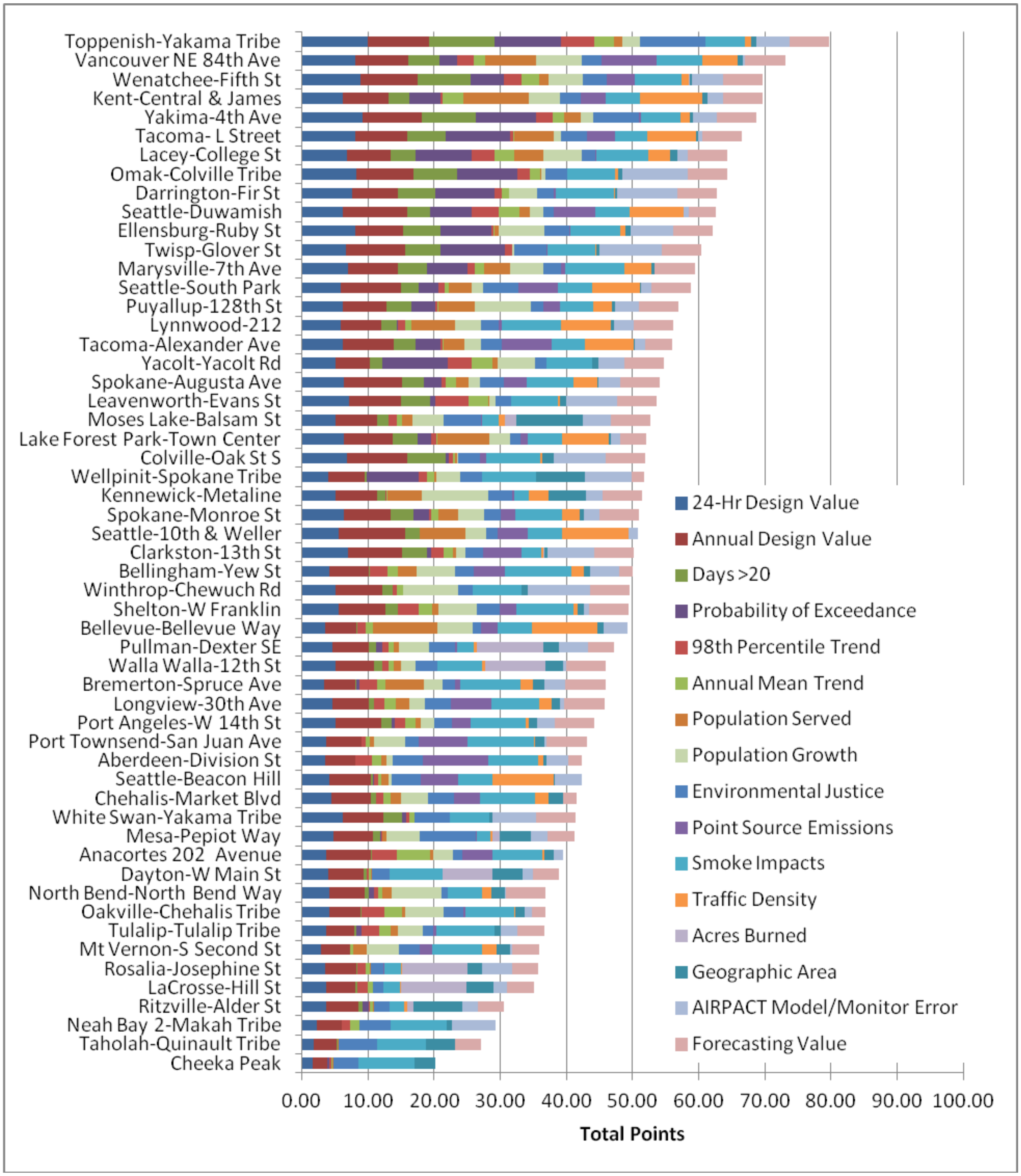


Figure 5. $PM_{2.5}$ decision matrix results

The methods for each criterion are summarized below, and the full rankings in each category can be found in the appendix. Unless otherwise noted, all calculations were performed on five years of data when available (2010–2014). If the type of monitor changed during the 5-year period, data from the old and new monitors were merged into a single dataset.

Several sites, including Vancouver NE 84th Ave. and Wenatchee Fifth St., have changed locations during the 2010–2014 period. In these cases, data from the old and new sites were merged into a single dataset in order to have sufficient data to rank these sites. As air quality conditions may be different in these new locations, the scores related to measured concentrations may not fully represent measured values at the current sites. Ranking of these monitors should be interpreted with caution.

24-hour design value

Purpose: The 24-hour design value is an important metric for both human health and NAAQS compliance. It indicates the severity of short-term $PM_{2.5}$ exposure, one of a site's highest concentration days.

Methods: The form of the 24-hour design value is the 98th percentile 24-hour concentration per year, averaged over three years. For this assessment, the 5-year 98th percentile 24-hour concentration was calculated as a surrogate for the 24-hour design value for several reasons:

1. The 5-year 98th percentile represents the five years of data collected since the previous network assessment (2010–2014).
2. Three-year design values can only be calculated at sites with at least 50 percent data completeness in each quarter. In 2014, 16 sites did not meet this criteria and did not have reportable design values. Extending the dataset to a full five years allowed design values to be calculated for all sites. The larger dataset reduced bias from missing or incomplete quarters.
3. The 98th percentile 24-hour concentration in a given year can sometimes be a sample collected during an exceptional event such as a wildfire if that event spans more than 2 percent of the year (approximately eight days). Using the 98th percentile of five years of data minimized the influence of exceptional events. Exceptional events would have to comprise at least 36 days of a 5-year sample period to influence the 5-year 98th percentile, which is far less likely than eight days in an individual year.
4. For sites with valid 2014 3-year design values, these design values were highly correlated with 5-year 98th percentiles ($r = 0.98$), indicating that the 5-year 98th percentile is a reasonable surrogate for 3-year design values.

Annual design value

Purpose: The annual design value represents typical, chronic $PM_{2.5}$ exposure over the long term.

Methods: The 5-year mean 24-hour concentration was calculated as a surrogate for the annual design value. Similar to the reasons stated above, this method was selected to minimize bias from missing data in the most recent 3-year period and to cover the full five years of data collected since the previous network assessment.

Days over 20 μg/m³

Purpose: Ecology strives to keep $PM_{2.5}$ concentrations below its healthy air goal of 20 μg/m³. Frequent exceedances of this goal indicate greater health concerns.

Methods: The number of 24-hour concentrations greater than 20.4 μg/m³ was divided by the number of total valid 24-hour concentrations. Sites with the highest percentages of days over 20.4 μg/m³ were given the highest scores.

Probability of a single day over 35 μg/m³

Purpose: Frequent exceedances of 35 μg/m³ at a site indicate a high risk of violating the 24-hour NAAQS. On days when $PM_{2.5}$ concentrations exceed this threshold, pollution levels are considered unhealthy for all individuals.

Methods: Maximum likelihood estimation methods were applied to the highest eight 24-hour concentrations per year at each site to yield the probability of a single day over 35 μg/m³ in a given year. Concentrations on days known to be impacted by wildfire smoke were excluded from the probability analysis. Sites with the highest probability of an exceedance were given the highest scores.

Trend

Purpose: Sites at which concentrations are rising rapidly are potential targets for more intensive monitoring and/or interventions to reduce emissions. Sites at which concentrations are declining rapidly are potential targets for less intensive monitoring.

Methods: The trend in deseasonalized 98th percentile 24-hour average concentrations and deseasonalized mean 24-hour average concentrations were computed as Δ μg/m³/year. Concentrations on days known to be impacted by wildfire smoke were excluded from the trends analysis. The absolute values of the two trends were then normalized and summed. Sites with the largest absolute value trends were given the highest scores.

Population served

Purpose: Monitors in dense population centers provide information on the exposures of a large number of people.

Methods: The population living within each monitor's geographic area served was extracted from the 2013 American Community Survey. Sites serving the largest populations were given the highest scores.

Population growth

Purpose: Monitors in areas of rapid population growth are of particular interest because concentrations may rise in tandem with growth and development. These sites may be candidates for more intensive monitoring in the future.

Methods: The population living within each monitor's geographic area served (see below) was extracted from the 2010 and 2000 censuses. The population growth rate was calculated as the rate of change in population between the decennial censuses. Sites with negative population growth were given a score of zero. Sites with the highest rates of positive population growth were given the highest scores.

Environmental justice index

Purpose: Ecology is committed to protecting the residents of Washington State from environmental and health hazards without regard to race, income, education, culture, national origin, or other demographic factor. Central to Ecology's commitment to environmental justice is the equitable provision of services among the state's demographic groups. Low-income and communities of color typically face higher burdens of environmental pollution and greater susceptibility to environmental health hazards, including air pollution. In light of this, environmental justice is an important consideration in the distribution of monitoring resources. Monitoring sites in communities with environmental justice concerns provide additional value to the network on the air pollution exposures of historically under-represented and under-served populations.

Methods: Four socioeconomic indicators were extracted from the 2013 5-year American Community Survey within each monitor's geographic area served:

1. Linguistic isolation (percent of households without a member who speaks English "very well" or better)
2. Low educational attainment (percent of individuals 25 years and older without a high school diploma or equivalent)
3. Poverty (percent of individuals living below 200 percent of the federal poverty level for their household size)
4. Unemployment (percent of the civilian work force both eligible and unemployed)

Percentages for each indicator were normalized to a scale of 0–10 and summed. This method of tabulating environmental justice scores was developed by the California Office of Environmental Health Hazards (OEHHA, 2014). Sites with the highest percentages in each socioeconomic category were given the highest scores.

Point source emissions

Purpose: Residents living in the proximity of large point sources of $PM_{2.5}$ may be concerned about the impacts of those sources on their air quality. Monitoring sites near these sources provide valuable information about these impacts. Even if $PM_{2.5}$ concentrations at these sites are low, these sites provide value to the public over and above their monitored concentrations.

Methods: Annual $PM_{2.5}$ emissions from point sources within a 15-mile radius of each monitoring site were extracted from the 2011 National Emissions Inventory. Emissions were downweighted exponentially by distance between the point source and the monitoring site and summed. Sites with the highest total distance-weighted emissions were given the highest scores.

Smoke impacts

Purpose: Rural areas of Washington State have many small communities whose air quality is heavily impacted by emissions from residential wood combustion and outdoor burning. These communities frequently experience poor air quality conditions during winter inversions. Monitoring sites in smoke-impacted communities provide valuable information about the relationship among meteorology, smoke emissions, and ambient concentrations of $PM_{2.5}$ in these small areas.

Methods: $PM_{2.5}$ emissions from residential wood combustion and residential outdoor burning were extracted by county from the 2011 Washington Comprehensive Emissions Inventory. The sum of these emissions was divided by the population of the county as a surrogate for smoke impacts. Each monitor was given the smoke score of the county in which it is located. Sites with the highest smoke emissions per person were given the highest scores.

Traffic density

Purpose: Vehicle emissions are a major source of $PM_{2.5}$ emissions, particularly in urban areas. Near-road pollution concentrations and patterns are a topic of heightened interest in the research community. Monitored $PM_{2.5}$ values collected near heavily trafficked roadways can be analyzed to identify rates of dispersion and decay of vehicle emissions.

Methods: Average annual daily traffic (AADT) counts collected by the Washington State Department of Transportation (2013) were extracted on arterial roadways within 4 miles of each monitoring site. AADT counts were multiplied by the length of the roadway on which the counts were collected and summed to yield total AADT-miles within each site's 4-mile radius. Sites with the highest number of AADT-miles were given the highest scores.

Agricultural and non-residential outdoor burning

Purpose: While residential outdoor burning is captured in the 'smoke impacts' score, air quality conditions may also be affected by agricultural and non-residential outdoor burning. Monitors in the proximity of these activities provide valuable information on the air quality impacts of larger-scale outdoor burning.

Methods: Permitted acres burned in 2014 were extracted for each county from the agburn database and normalized to the total land area of the county. Each monitoring site was given the normalized acres burned score of the county in which it is located. Sites with the highest ratio of acres burned to total land area were given the highest scores.

Geographic area served

Purpose: The density of monitoring sites is typically much lower in rural areas than in urban areas. In rural areas, monitors may be spaced hundreds of miles apart. Isolated monitoring sites provide additional value to the network because they are the only available sites between great distances.

Methods: First, Thiessen polygons were drawn around each monitoring site to define the outer boundary of each monitor's geographic area. Thiessen polygons are a geographic tool that delimits the area closer to each monitor than any other monitor. Next, median predicted $PM_{2.5}$ concentrations from the AIRPACT-3 model over the 2010–2013 period were plotted for 12 km grid cells across Washington and neighboring states. The ratios between these median $PM_{2.5}$ predictions and 24-hour design values measured at each monitoring site were calculated. Ratios between median predicted $PM_{2.5}$ and 24-hour design values were also calculated for border sites in British Columbia, Idaho, and Oregon using 2011 monitoring data. Several "dummy" sites in the Pacific Ocean were included with design values of 5 $\mu g/m^3$ to minimize bias from edge effects along the shoreline. These ratios were interpolated between monitoring sites using a $1/distance^2$ algorithm and multiplied by the median predicted $PM_{2.5}$ at each grid cell. This process yielded modeled $PM_{2.5}$ concentrations forced to monitored 24-hour and annual design values for a 12 km grid across the state and surrounding area (see Figure 6 and Figure 7).

Next, modeled grid cells within each monitor's Thiessen polygon were compared with the modeled 24-hour design value nearest to each monitoring site. Cells whose modeled 24-hour design value deviated from the modeled design value at the monitoring site by more than 5 $\mu g/m^3$ in either direction were erased from the monitor's polygon. The remaining area in each monitor's polygon is the area meeting both criteria: (1) closer to that monitoring site than any other, and (2) comparable in modeled values within a +/- 5 $\mu g/m^3$ margin of error. Eliminating areas with very different modeled concentrations reduced each monitor's geographic area to only areas with similar airshed characteristics (see Figure 8).

The number of square meters within each monitor's geographic area represented was then extracted. Sites with the largest geographic areas represented were given the highest scores.

A map showing the names and locations of monitoring sites operated by Ecology and its partners can be found on the Washington State - Air Monitoring webpage at https://fortress.wa.gov/ecy/enviwa/. This map can be cross-referenced against the maps below to identify the names of individual monitoring sites.

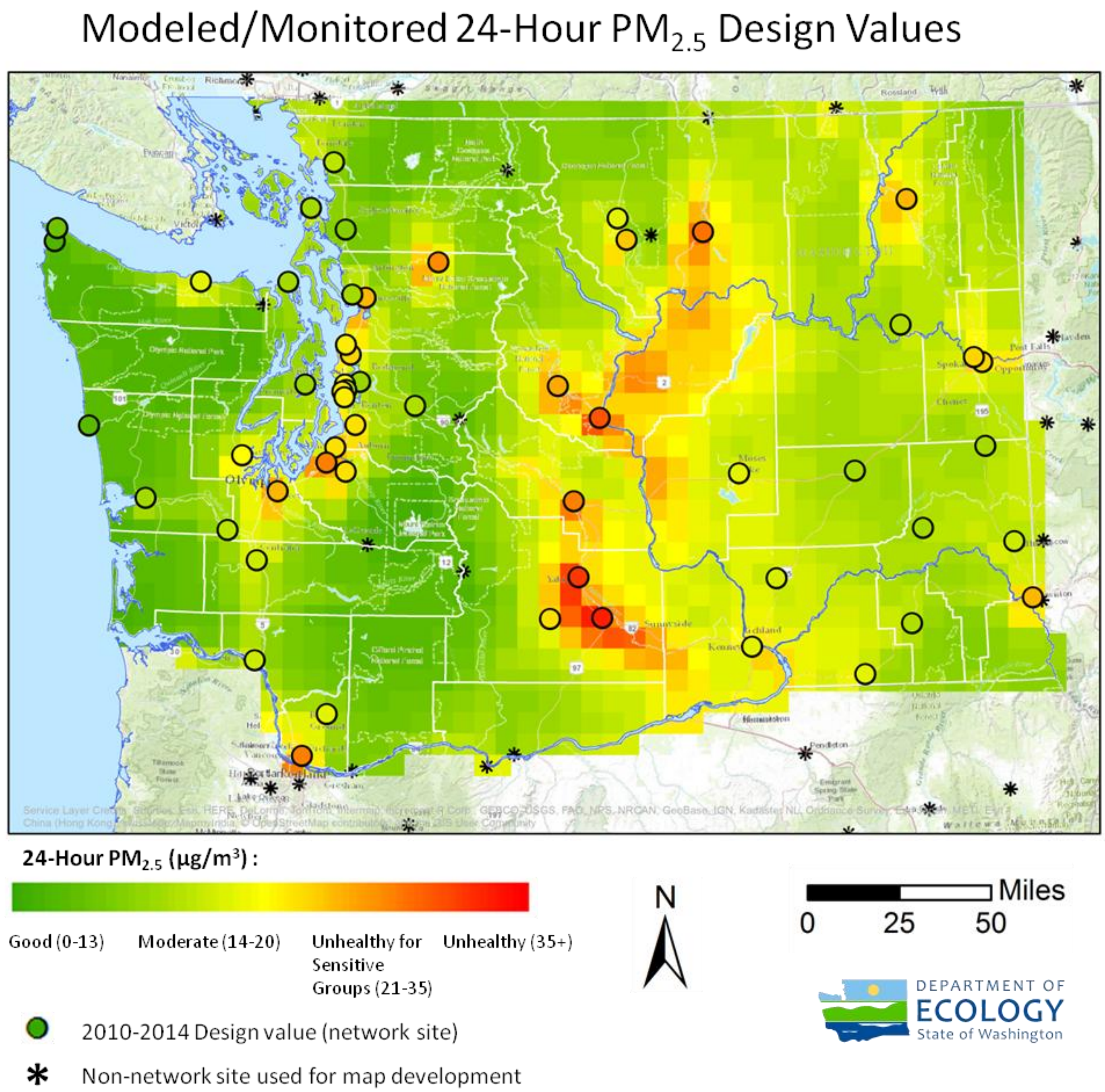


Figure 6. Modeled/monitored 24-hour $PM_{2.5}$ design values

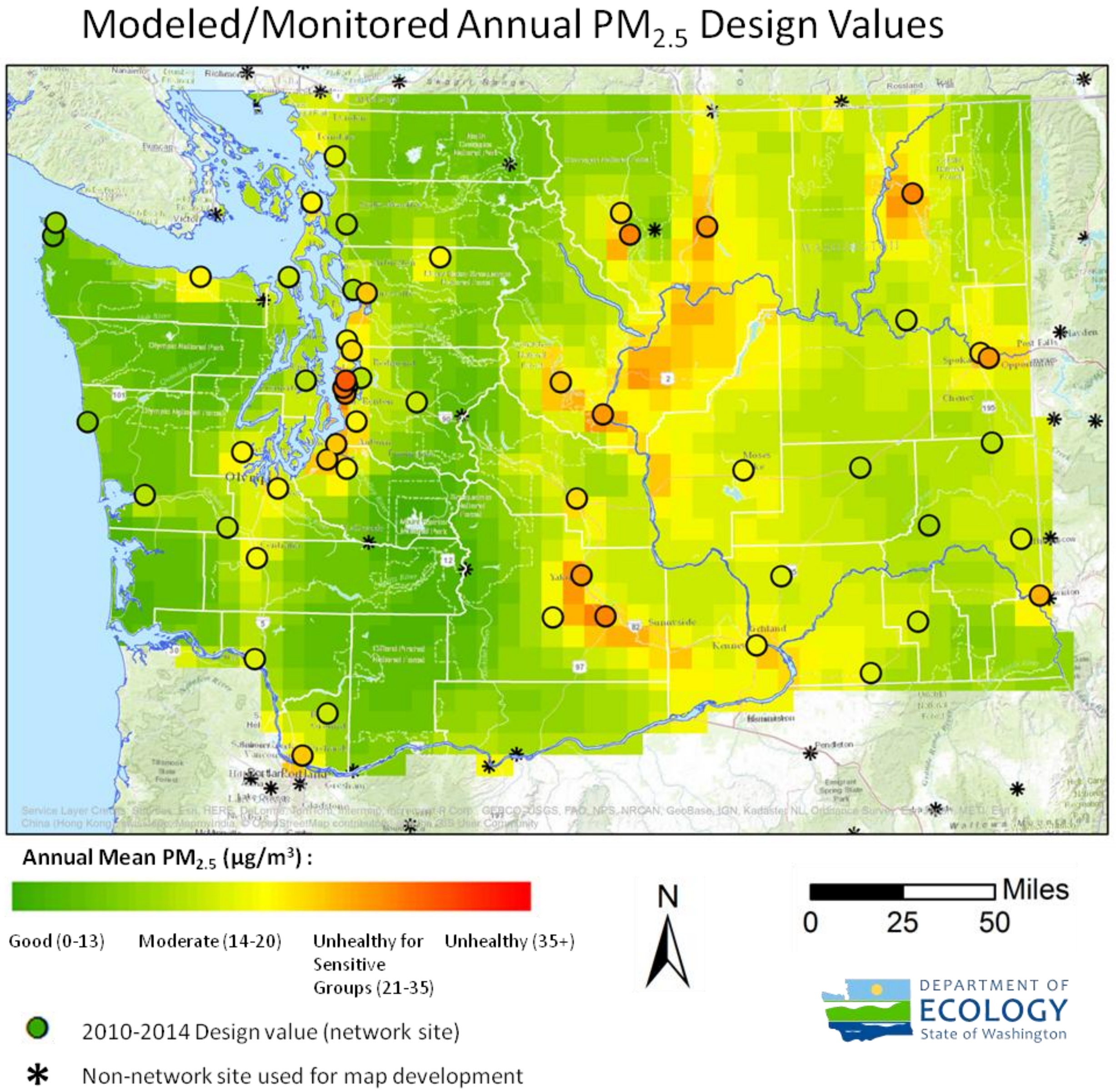


Figure 7. Modeled/monitored annual $PM_{2.5}$ design values

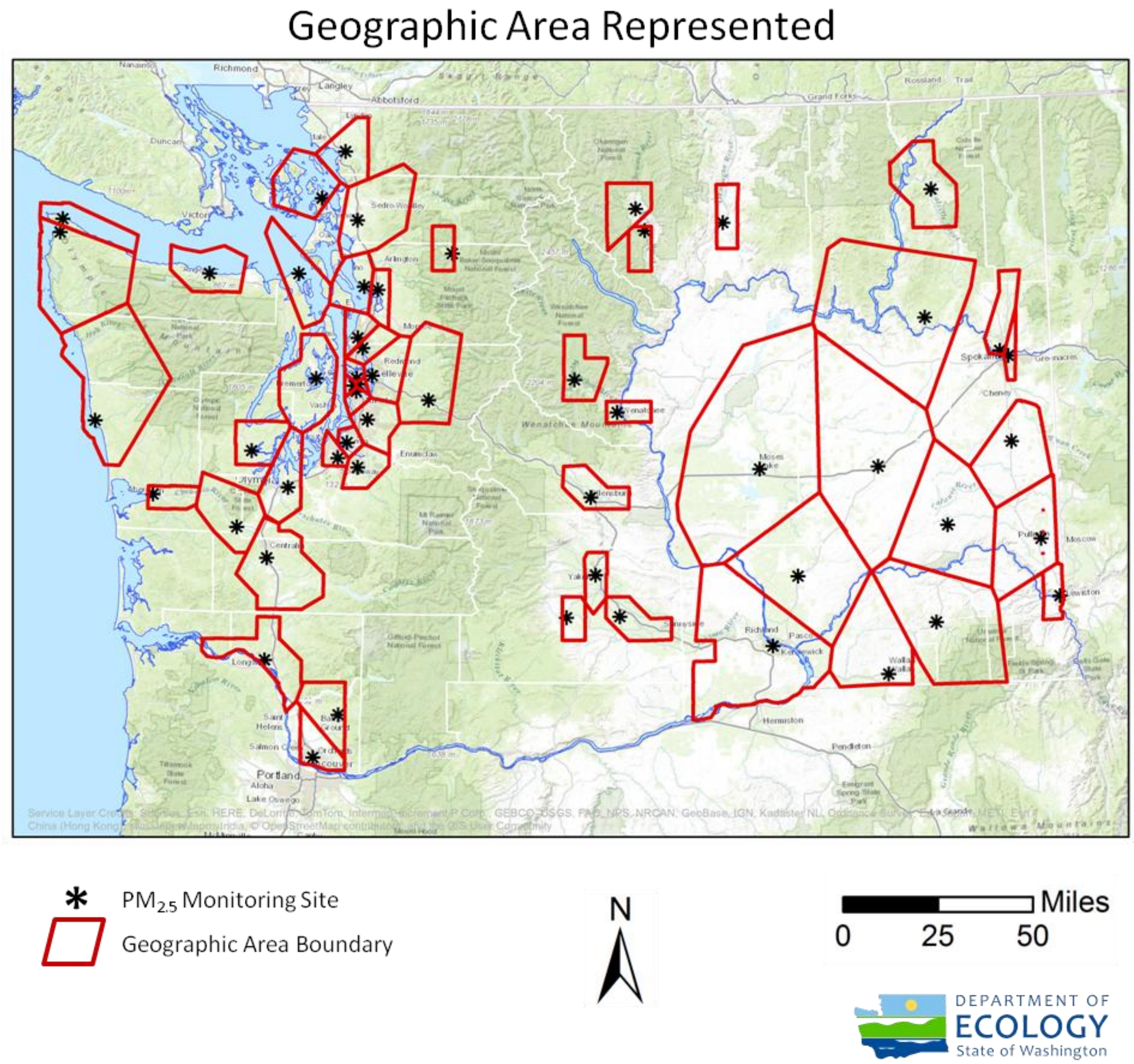


Figure 8. Geographic area represented by each monitoring site

Error between AIRPACT model and monitor

Purpose: The Air Indicator Report for Public Awareness and Community Tracking (AIRPACT) model provides daily air quality forecasts for the Pacific Northwest. Model performance varies across the state and is often dependent on meteorological conditions. In areas with poor model performance, monitoring data provides additional value because model predictions are less accurate. In addition, monitors also provide researchers with crucial data to assess and subsequently improve model performance.

Methods: Fractional bias (FB) was calculated by comparing model predictions to monitored values at each site using the following equation:

$$FB = \frac{1}{N}\sum_{i=1}^{N}\frac{(C_m - C_o)}{\left(\frac{C_o + C_m}{2}\right)}$$

Where:

C_m is the modeled daily mean $PM_{2.5}$ concentration
C_o is the observed daily mean $PM_{2.5}$ concentration
N is the number of days when both measurements were available for comparison

Sites with the highest FB (poorest model performance) were given the highest scores.

Forecasting value

Purpose: Ambient monitors provide one vital piece of information when making air quality forecasts and burn management decisions. The ERO-managed agricultural burn permitting program makes use of the above mentioned "agburn sites." CRO, ERO, DNR, and several LAAs assess data from different monitors before authorizing outdoor and silvicultural burning, including ditch burning, orchard tearouts, pile burns, and other yard debris disposal. Various monitors are used to forecast wildfire smoke. Decisions to curtail wood burning during home heating season (i.e., "burn bans") are partly based on monitor readings in the affected community.

Methods: Past experience and best professional judgment was used in ranking sites. Monitors that are used as described above were ranked on a scale of 0 (unimportant, hardly used for these purposes), 1 (slightly important), 2 (used occasionally) and 3 (very important, constantly checked for the presence of smoke).

Comparing selected $PM_{2.5}$ sites

Rather than compare all network $PM_{2.5}$ sites against each other to check for redundancies and opportunities to consolidate, five site pairs were manually identified as being potentially representative of each other. If one site is almost always runs higher than the other, it might be acceptable to discontinue the lower site because the higher site would result in air quality management actions that are more protective of public health. The site pairs are:

- Oakville (Neph, met) and Chehalis (Neph)
- Tulalip (Neph) and Marysville (FEM, Neph, met)
- Spokane- Monroe (Neph) and Spokane- Augusta (FEM, FRM, met)
- White Swan (Neph) and Toppenish (Neph and met)
- Lake Forest Park (Neph) and Lynnwood (FEM, met)

Comparisons were based on 24-hour averages of $PM_{2.5}$ since 2010. Six plots were made per site pair and are shown in Figure 9 through Figure 13. An explanation of each of the six plots follows:

- The top left panel is a quantile- quantile plot, showing how the two distributions compare. When above the 1:1 line, it suggests that the values on the y-axis are *consistently* higher than those on the x-axis.
- The top center panel shows how the difference between the two sites varies as the concentration of one site changes. Increasing differences at higher concentrations suggest that the sites have distinctly different characteristics and aren't necessarily redundant.
- The top right panel shows differences between the two sites as a function of time. This helps see whether differences are confined to a few events or when they occur consistently.
- The bottom left and center panels break down these differences by month and day of week, helping isolate seasonal difference and those linked to the work week.
- The bottom right panel shows boxplots of the two sites by year. This helps see differences in data distribution, and if they are confined to a few years.

Some important observations:

- Chehalis consistently runs higher than Oakville. This is true on a seasonal and annual basis. As such the monitor at Chehalis will provide a conservative estimate of $PM_{2.5}$ levels in Oakville. The Oakville monitor does have some access and siting issues and its discontinuance will not significantly burden air quality management efforts. There are few uses for meteorology recorded there.
- Tulalip is almost always lower than Marysville, and the latter can easily serve as a conservative proxy. This is a single pollutant site and can be discontinued with no significant loss of information.
- The Spokane-Monroe site does offer some information that the site at Augusta Ave. does not capture. The Monroe site often runs marginally higher during wintertime weekends. This is understandable site the Monroe site is located in a residential neighborhood, while the Augusta site is located in a predominantly light industrial/commercial area. It is a sufficiently valid reason to keep the site operational, and assist with burn bans. As this site is located on the ERO building, it is not a significant overhead to operate.
- Toppenish is almost always higher than White Swan, with seasonal, day of week and annual patterns strongly pointing in the same direction. As both sites are on the Yakama reservation, the former will provide a sufficiently conservative estimate of $PM_{2.5}$ on the tribal lands even if the White Swan site were discontinued. However, due to high values at Toppenish during the heating season, additional monitors such as White Swan can be of value in determining the spatial extent of elevated $PM_{2.5}$ levels in the area.
- Lake Forest Park routinely runs higher than the Lynnwood site and they represent different airsheds. It is recommended that both sites are continued.

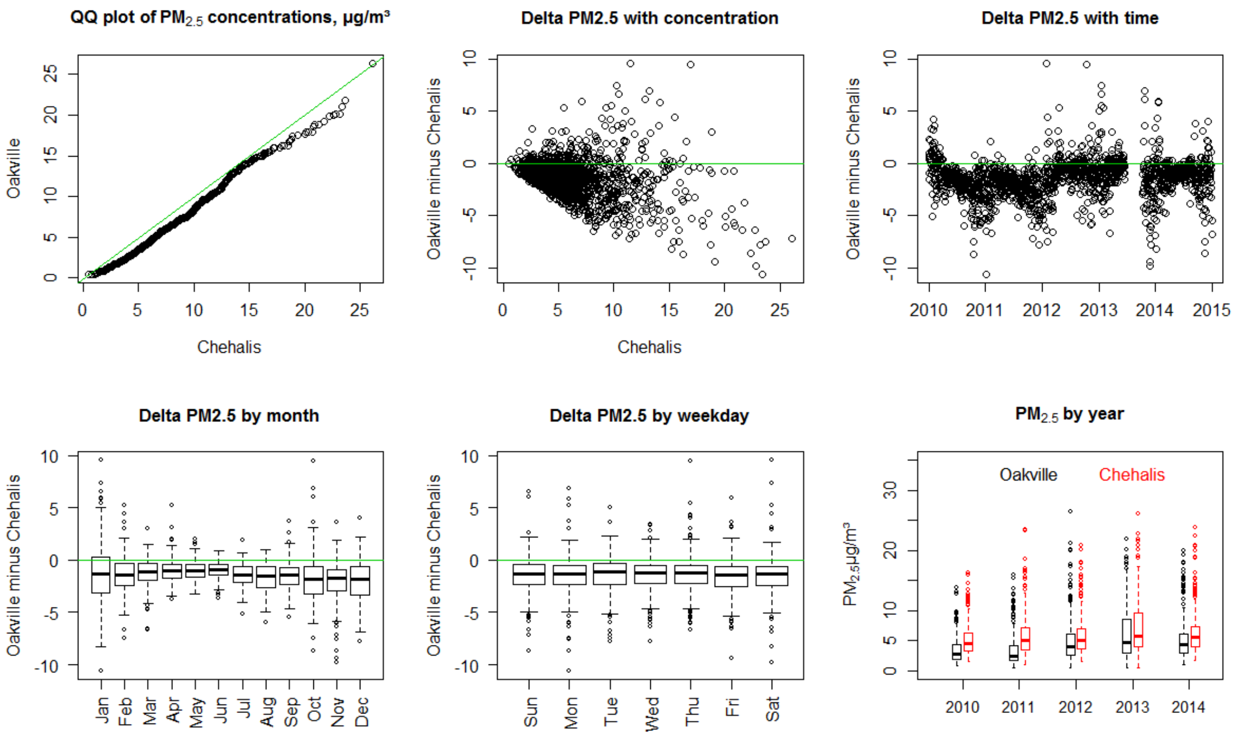


Figure 9. Comparing $PM_{2.5}$ at Chehalis and Oakville

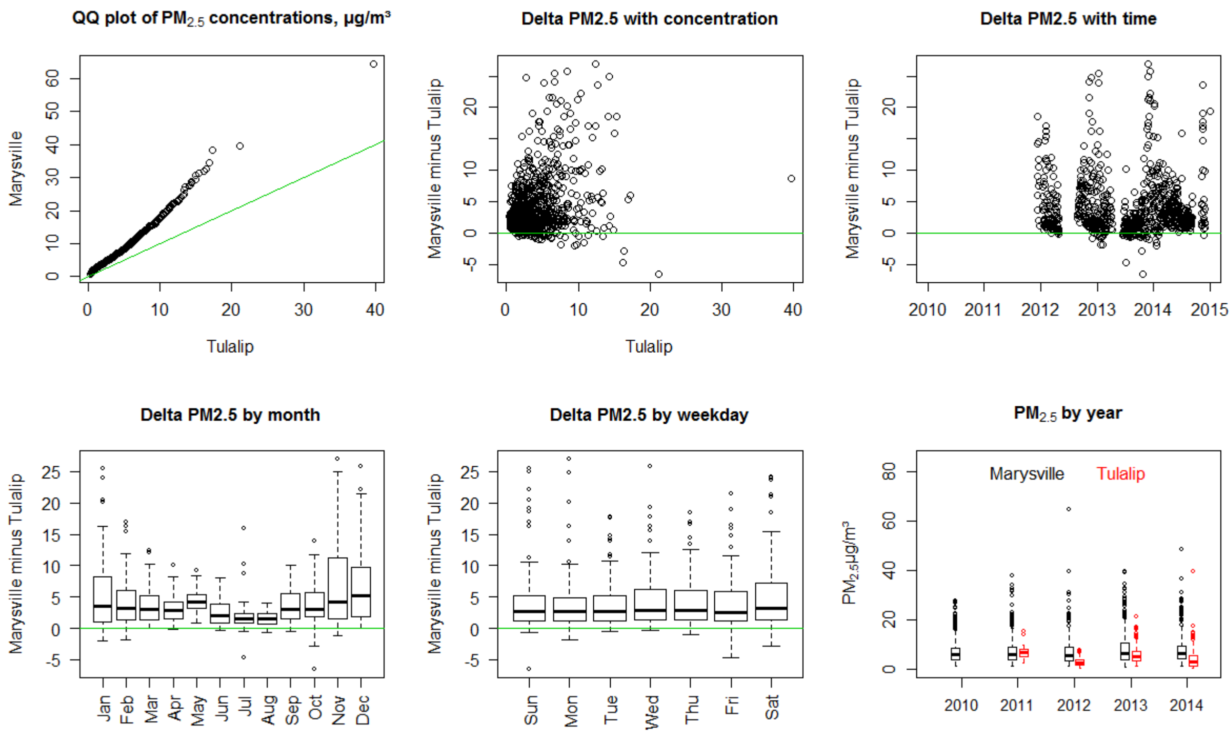


Figure 10. Comparing $PM_{2.5}$ at Tulalip and Marysville

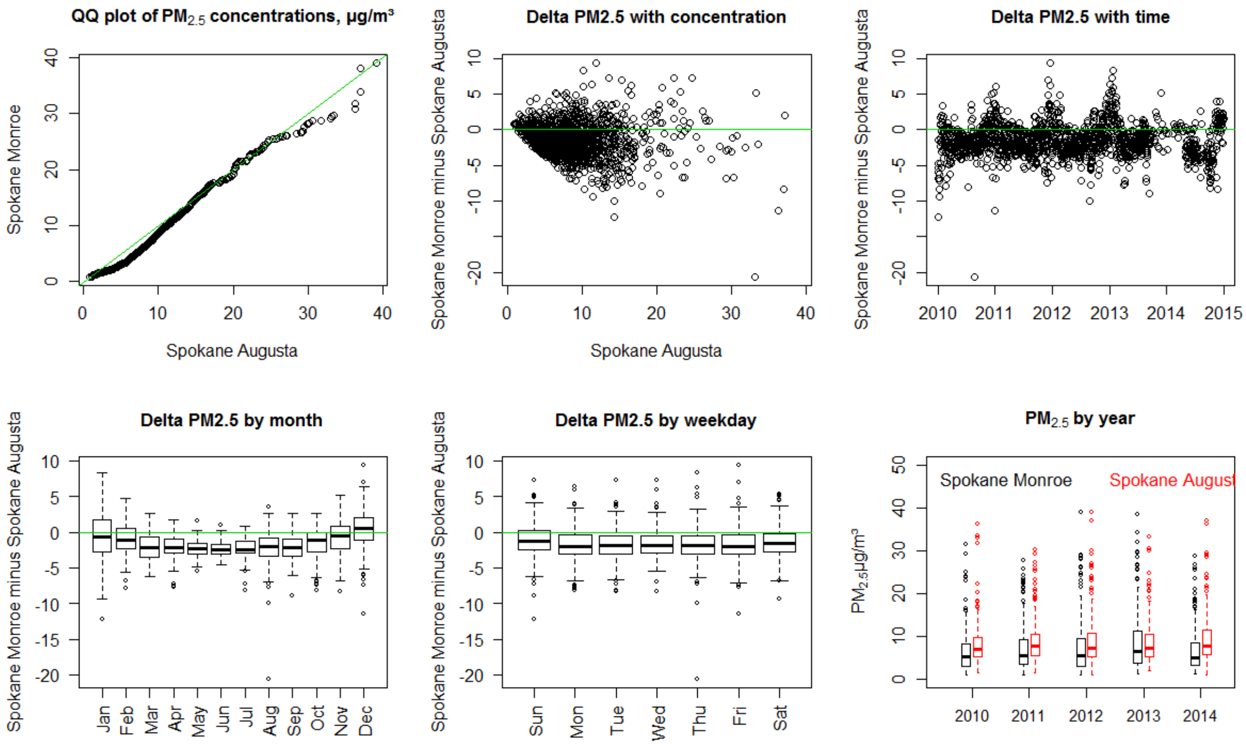


Figure 11. Comparing $PM_{2.5}$ at Monroe Ave. and Augusta Ave. in Spokane

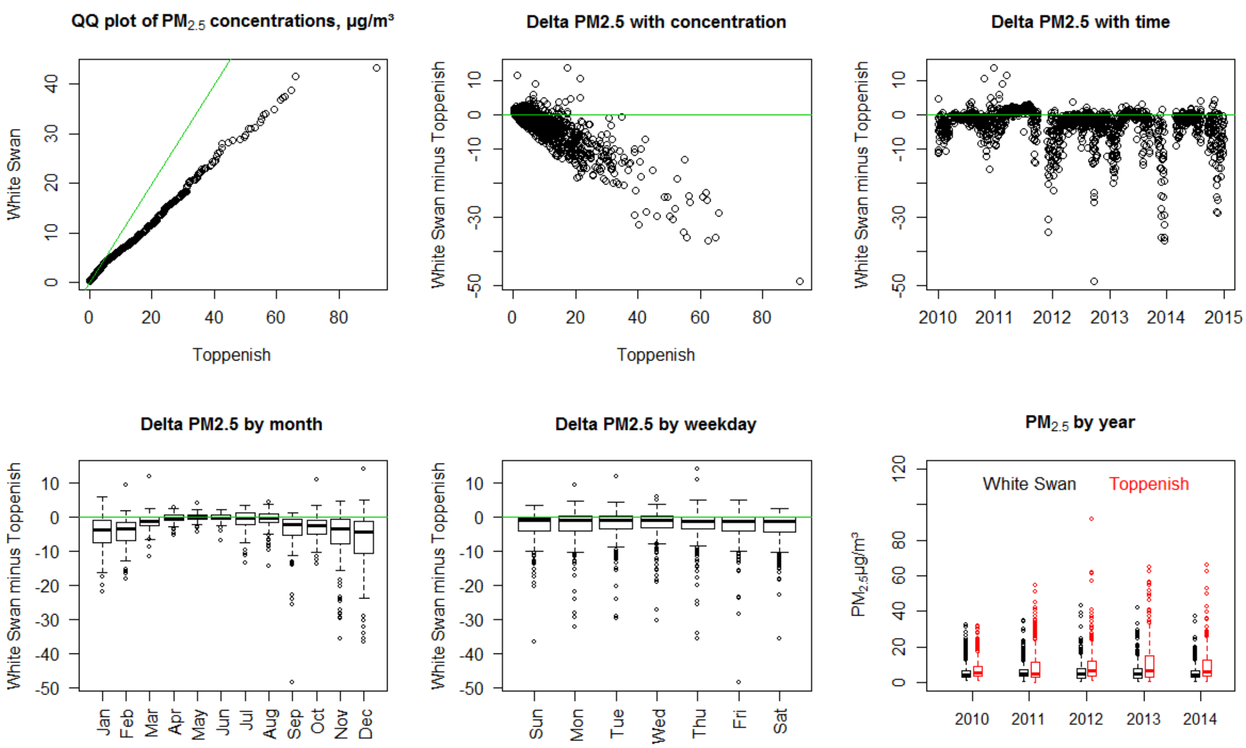


Figure 12. Comparing $PM_{2.5}$ at Toppenish and White Swan

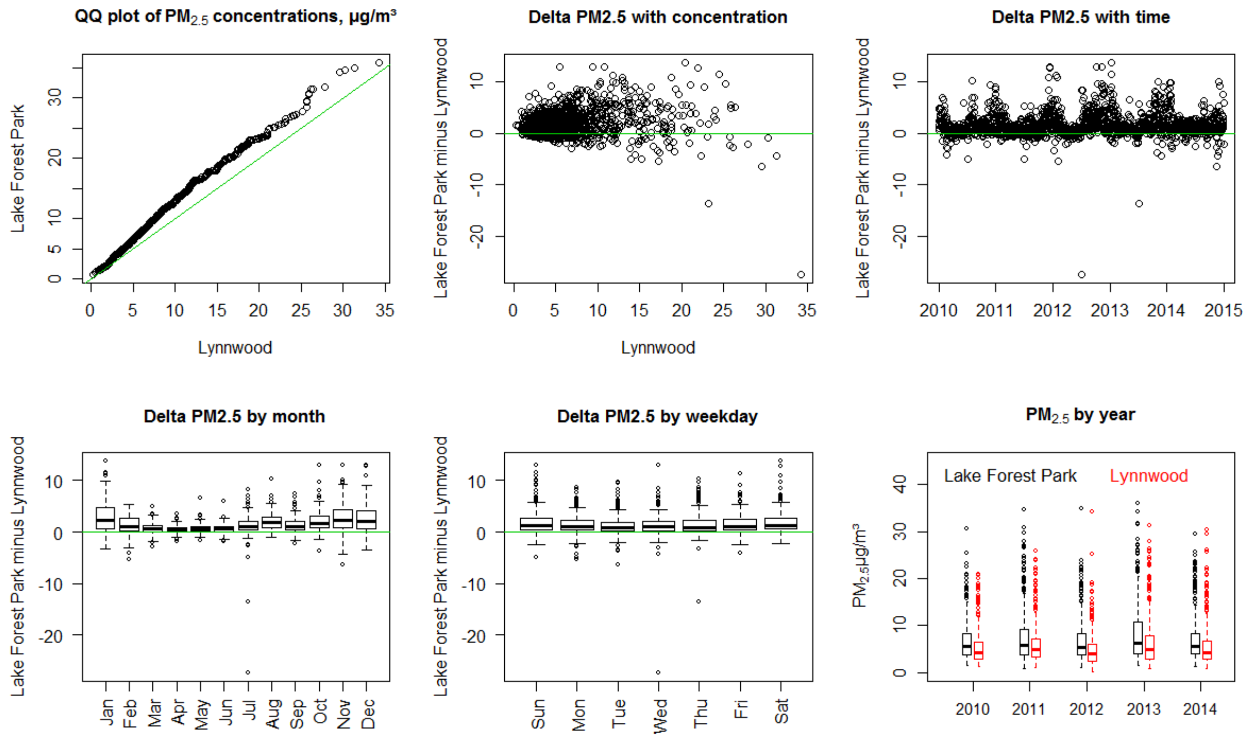


Figure 13. Comparing $PM_{2.5}$ at Lynnwood and Lake Forest Park

Agburn Network Analysis

Sites used to manage smoke from agricultural burning ("Agburn sites") are the result of a legal agreement and despite relatively low rankings of these sites in the decision matrix, provide the Air Quality Program with valuable information. These eight monitors (Walla Walla, Mesa, Dayton, Pullman, Ritzville, LaCrosse, Rosalia, and Moses Lake) provide data used on a daily basis when ERO makes agricultural burn decisions. Other than Walla Walla, which is impacted by wintertime wood smoke, these monitors record elevated $PM_{2.5}$ concentrations mostly during the daytime hours of late summer and fall. While there are other monitors around the state used for burn management work, they are mostly multi-purpose monitors that assist with wintertime woodstove curtailment calls, outdoor/ yard debris/ silvicultural burn management and wildfire smoke forecasts at different times of year. This section is devoted to using data from agburn sites to assess the effectiveness of the agburn program.

The agburn program is designed to minimize $PM_{2.5}$ impacts in communities, even unmonitored ones. While this analysis is not aimed at determining the efficacy of each and every burn call, it attempts to identify if there is a consistent trend in $PM_{2.5}$ levels at these sites, which might be attributable to agricultural burning. Data since the last network assessment (2010 onward) are considered. To minimize the interference of wildfires, all hours with $PM_{2.5}$ levels over 35µg/m³ were excluded from this analysis. While agburn plumes rarely produce concentrations over 35µg/m³, this threshold does not exclude persistent low level impacts from wildfires.

The overall number of agricultural acres burned fluctuates year to year for various reasons, even within the same crop type and county. As can be seen in Figure 14, Walla Walla, Whitman, and

Columbia counties account for much of the acres burned, and overall acreage burned is almost evenly split between spring and fall. Garfield County does not have its own $PM_{2.5}$ monitor, while Whitman County has three monitors at Pullman, Rosalia, and LaCrosse. Smoke from burning does not always impact monitors within the same county.

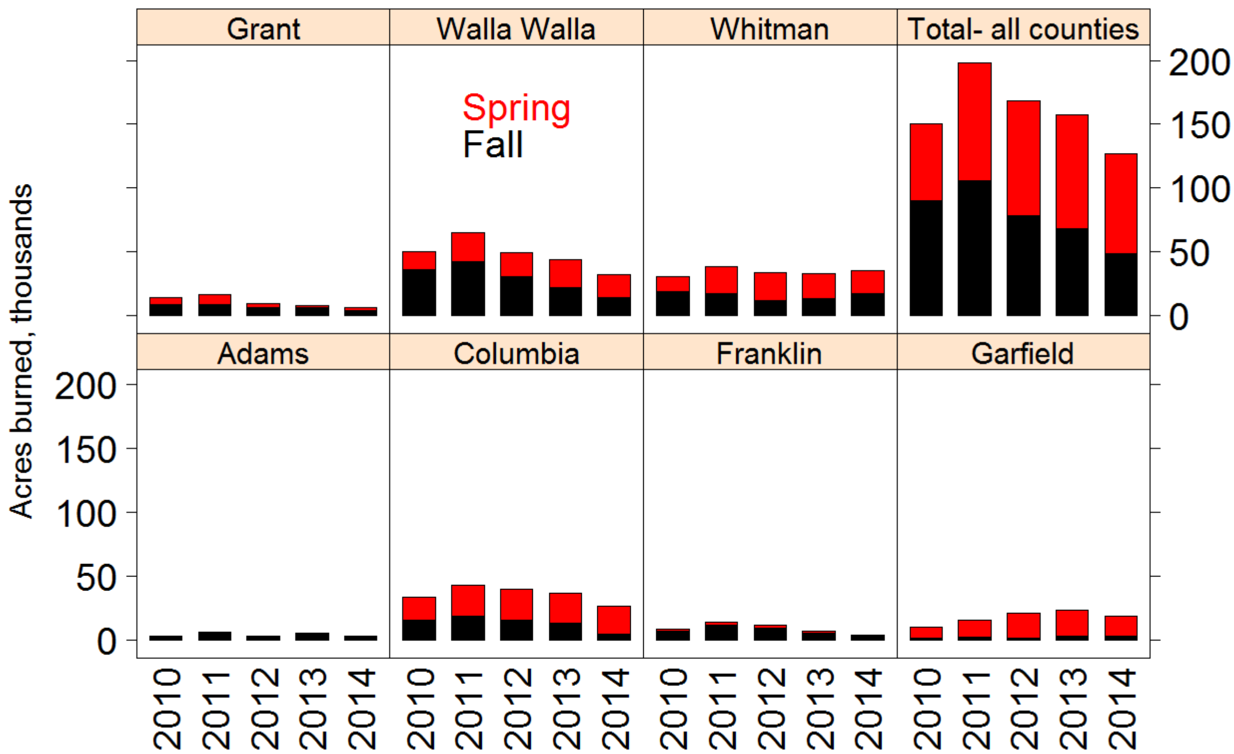


Figure 14. Acres of agricultural fields burned in each county since 2010

De-seasonalized monthly means of $PM_{2.5}$ over the last five years show no significant long term trends (Figure 15). The spike in September 2012 was due to large scale wildfires, which persisted for several weeks. The decline in 2014 in Walla Walla was due to an unusually clean home heating season.

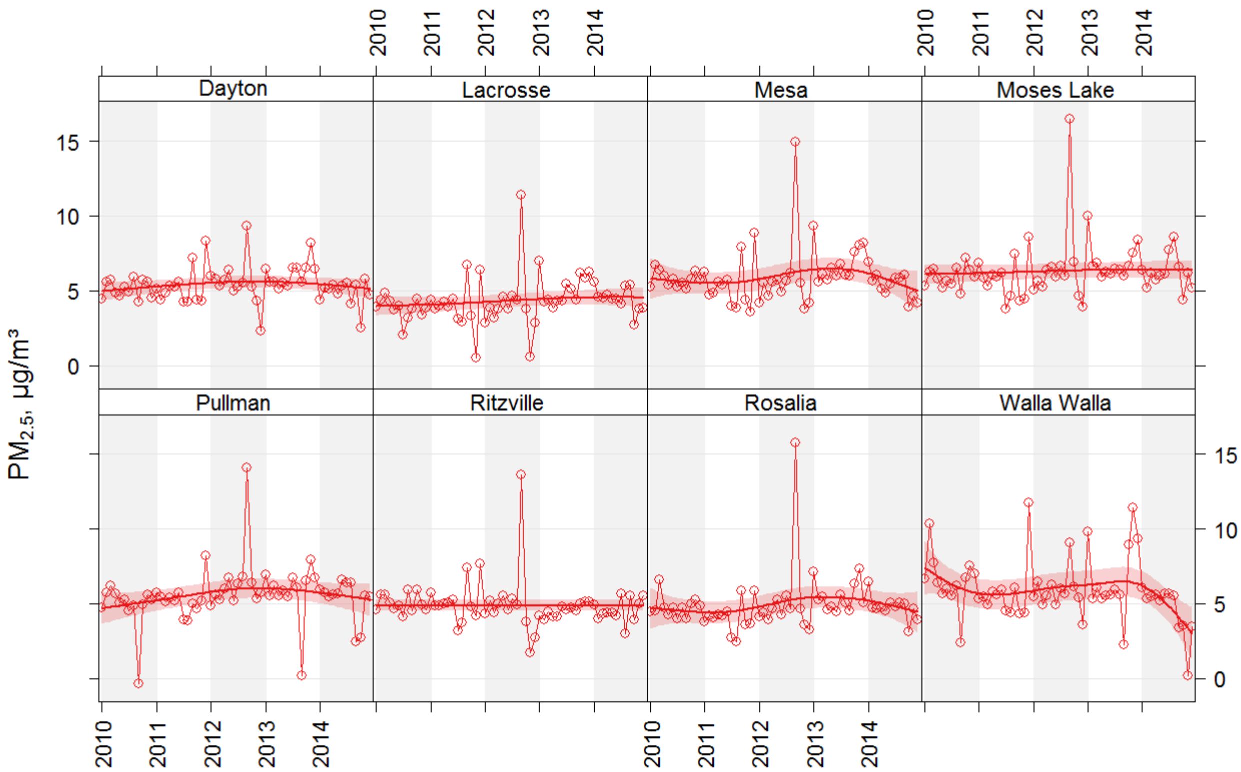


Figure 15. Trend of de-seasonalized monthly mean $PM_{2.5}$ at agburn sites

Even if the screening threshold were reduced to 25 µg/m³ in an attempt to minimize interferences from the 2012 wildfires, the 90th percentiles in the fall are at least 3 µg/m³ higher than those in the spring. Since there were no big seasonal differences in the acres burned or expected emission factors of $PM_{2.5}$ from the respective crop residue burned, the role of meteorology was investigated to see if differences could be explained. Co-located meteorological data are not measured at any agburn sites, but nearby airport data are available at Walla Walla, Pullman, and Moses Lake. Walla Walla airport was taken to be representative of conditions in Dayton. No mixing height data are available but wind speed can be used loosely as a proxy for atmospheric mixing.

Figure 16 shows seasonal polar frequency plots at four agburn sites. These plots display wind speeds and directions associated with hourly daytime (10AM- 6PM) $PM_{2.5}$ concentrations and help compare $PM_{2.5}$ levels under similar meteorological conditions. They do not compare the shift in speeds or directions by season. Areas of the plot that are white imply that combination of wind speed and direction did not occur. As an example: observe that Dayton $PM_{2.5}$ concentrations average about 5 µg/m³ when springtime winds are from the southeast quadrant, irrespective of wind speed. In the fall, corresponding concentrations average around 10 µg/m³. For the most part, the same wind speeds and directions give rise to higher concentrations in the fall than in the spring.

Therefore, unfavorable meteorology was not the *main* reason for higher fall concentrations. Instead these are likely caused by additional smoke pressures from burns less than 100 tons that do not require a permit, ditch burning, low level wildfire smoke impacts etc.
There are typically about five hours each spring when hourly $PM_{2.5}$ concentrations exceed 20 µg/m³. Fall numbers vary widely, but average about 45 across all sites. Comparison of daytime winds in spring and fall at these sites show fall winds to be about 1-2mph lighter on average. Even if this resulted in a quadrupling of hours with $PM_{2.5}$ > 20 µg/m³, it does not explain even half the observed high values.

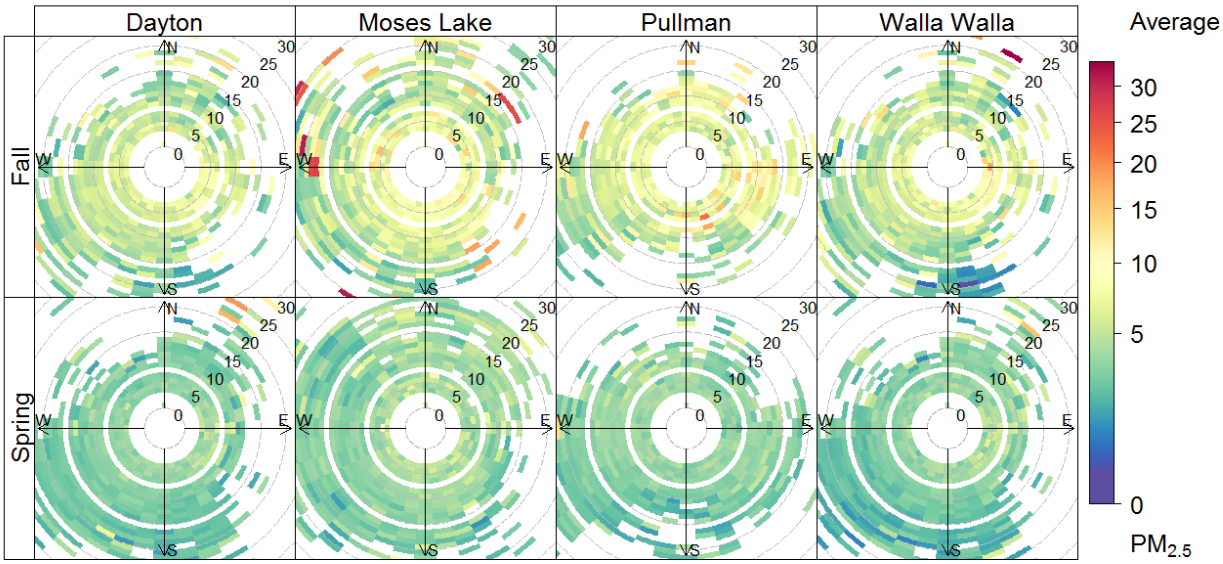


Figure 16. Seasonal polar frequency plots of mean daytime $PM_{2.5}$. Radial lines are wind speeds in mph

Summary

There have been no changes to the long term trend in $PM_{2.5}$ concentrations at agburn sites. $PM_{2.5}$ levels show little correlation with acres burned. The agburn program has kept $PM_{2.5}$ levels low at these monitoring locations and if its efficacy in springtime were reproduced in the fall, it would lead to fewer than 25 daytime hours a year when $PM_{2.5}$ concentrations at a single site exceed 20 µg/m³.

Ozone Background

Ecology and its partners operate a network of 13 continuous ozone monitors statewide. This network provides near-real-time data for a variety of users with a diverse array of data needs and applications.

Ozone data are used to determine compliance with the NAAQS, provide near-real-time information on air quality for public health protection through Ecology's WAQA and EPA's Air Quality Index (AQI), forecast air pollution episodes and make ozone action-day calls, and determine efficacy of control measures. Ecology's ozone network consists of FEM monitors.

In 2014, all ozone monitors in the Washington State network reported 8-hour design values below the federal standard of 0.075 ppm, as shown in Figure 17.

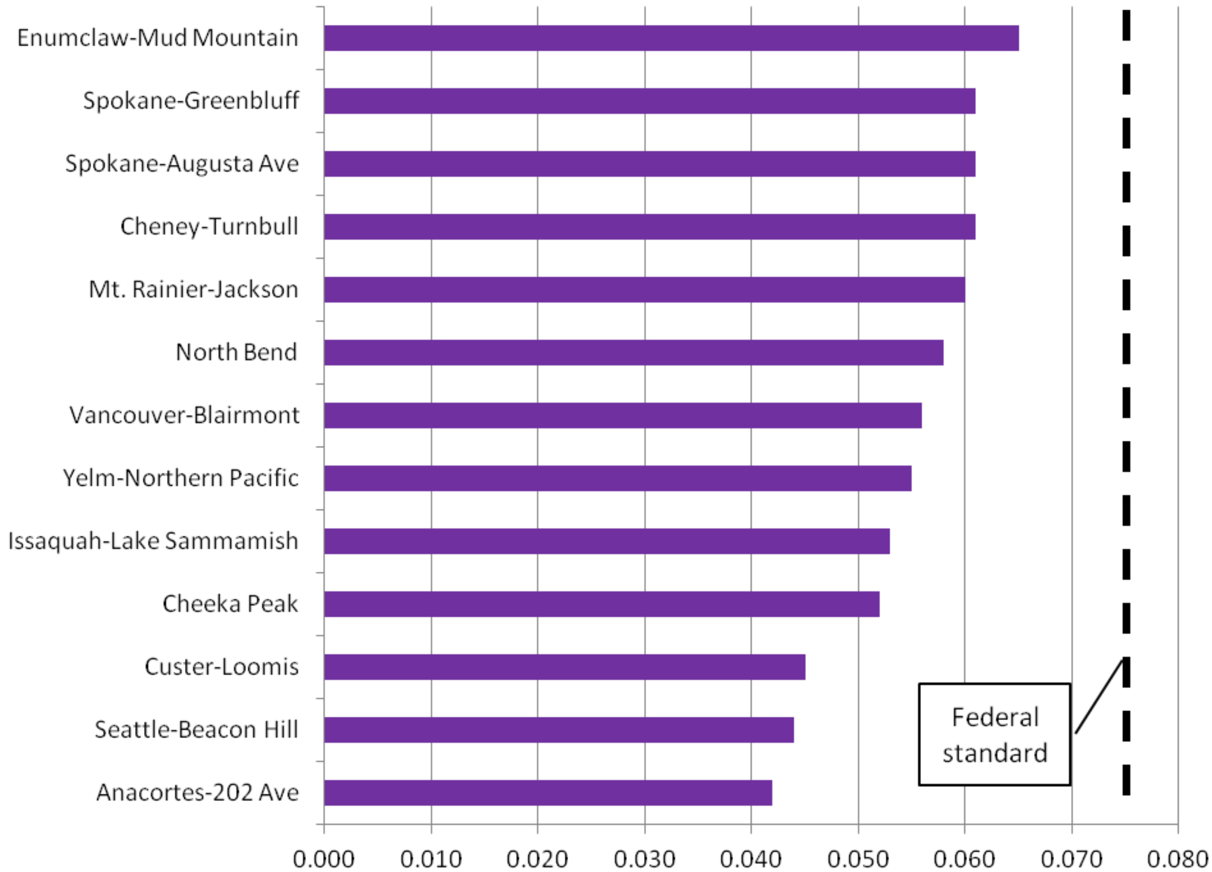
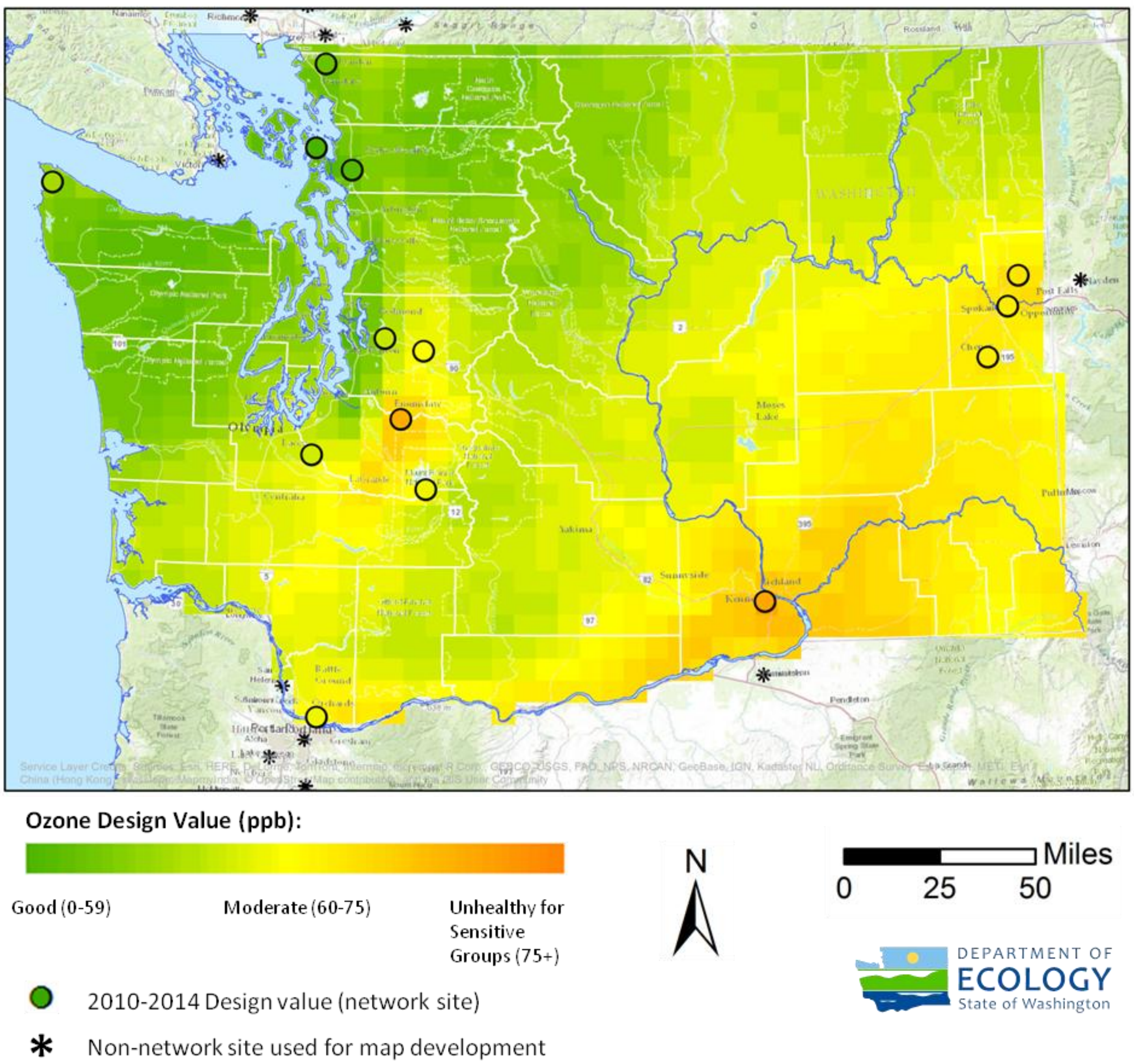


Figure 17. 2014 ozone 8-hour design values

Ecology used a decision matrix to analyze the official ozone monitoring network. Stations were ranked in order of value as informed by Ecology's monitoring policy goals and objectives. The decision matrix primarily emphasized the protection of public health. As elevated ozone concentrations are associated with a number of adverse health effects, the decision matrix ascribed higher scores to sites with higher measured pollutant concentrations and large populations represented. The synthesis of measured concentrations and population represented at each site acts as a surrogate for population exposure risk.

In contrast to many states elsewhere in the U.S., ozone precursor sources in Washington State are relatively less uniformly distributed. Ozone concentrations are relatively low in urban areas, because: (1) there are no major ozone-precursor-source regions upwind, (2) precursors have not yet undergone photochemical reactions during short travel times, and (3) background ozone is subject to NO_x titration. The highest ozone concentrations in Washington State occur in the relatively sparsely populated Western foothills of the Cascade Mountains, which lie downwind of the urban areas of the Puget Sound lowlands. High ozone events occur on hot summer days with low to moderate winds with a northerly component. As ozone precursors originating in different areas undergo photochemical reactions during transport, determining relative contributions of each source area is not straightforward. For these reasons, Ecology did not define airsheds and populations specific to each ozone monitor.

Modeled/Monitored Ozone Design Values



Ozone Decision Matrix

Scoring

The criteria included in the ozone decision matrix are summarized in Table 7 below. They fit roughly into three categories: measurement variables, social variables, and environmental variables.

Table 7. Ozone Decision Matrix Criteria

Category	Criterion	Units
Measurement	8-hour design value	ppb
	75th percentile	ppb
	Days over 65 ppb	%
	Probability of day over 70 ppb	%
	Trend	ppb/year
Social	Population served	# people
	Population growth	# people/10 years
	Environmental justice index	---
Environmental	Error between AIRPACT model and monitor	%

The values for each criterion were normalized to a scale of 0–10, with the highest value given a 10 and the remaining values scaled linearly relative to the maximum. The final results of the decision matrix are shown in Figure 18. Sites with the highest scores are considered to provide the greatest relative value to the Washington State network.

As with the rankings of $PM_{2.5}$ sites, the final ozone site rankings should be interpreted with caution. As with any summary statistic, the scores in each criterion have an implicit margin of error, and these margins of error are aggregated in the final scores. In addition, while every attempt was made to scale and synthesize the scores in the most objective manner possible, small adjustments in these methods can lead to changes in the final site rankings. Therefore, differences of <5 points in the final scores are likely not significant. It is recommended that the final values be interpreted in broader quantiles rather than as specific scores. For example, a site ranked among the top 10 can be assumed to provide greater value than a site ranked in the bottom ten. However, a site with 50 points cannot be assumed with confidence to be significantly more valuable than a site with 49 points.

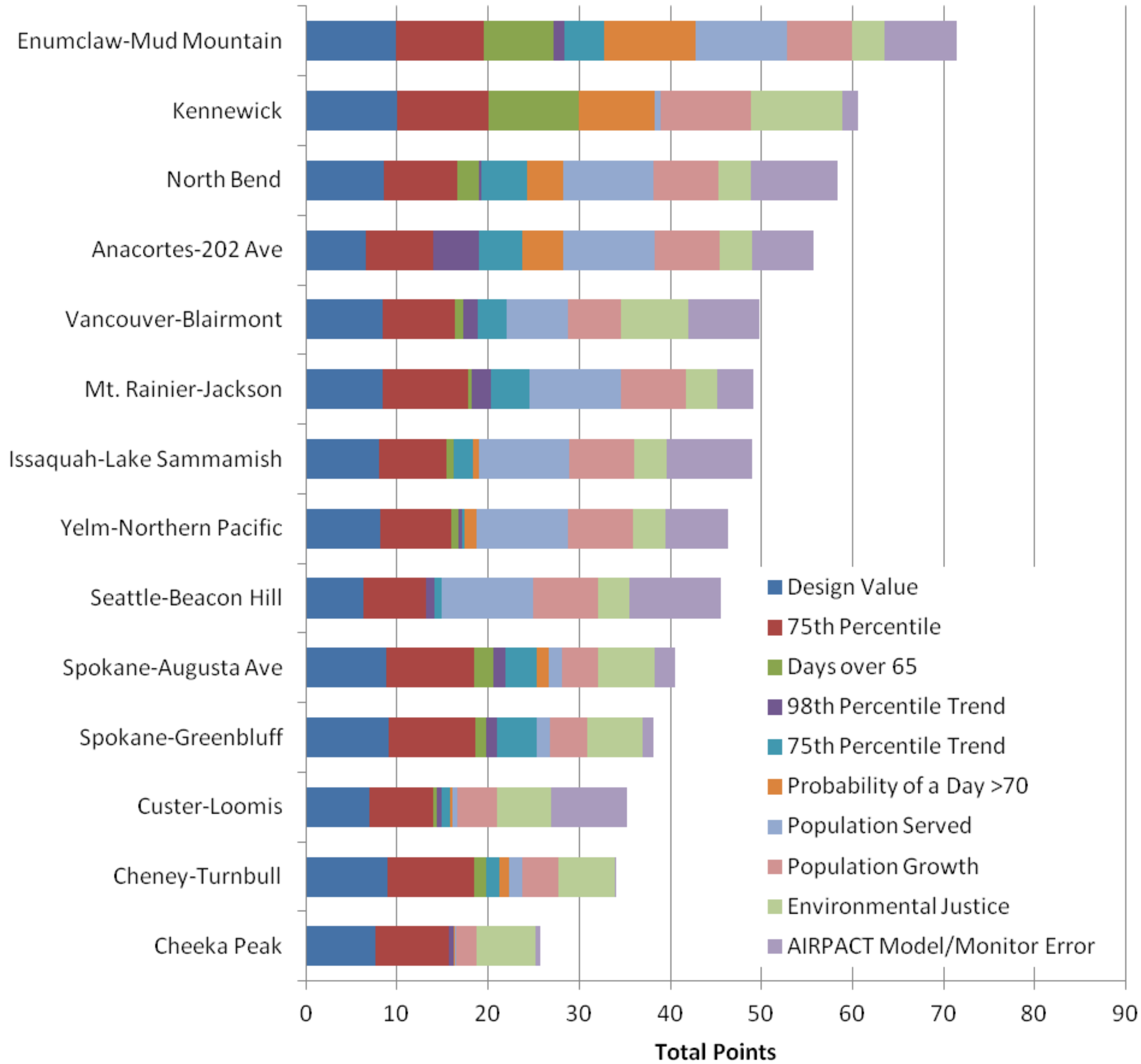


Figure 18. Ozone decision matrix results

The methods for each criterion are summarized below, and the full rankings in each category can be found in the appendix. Unless otherwise noted, all calculations were performed on 5 years of data when available (2010-2014).

8-Hour design value

Purpose: Design values are used to determine compliance with the NAAQS. They also provide information on acute exposure to ozone on the highest concentration days of the ozone season.

Methods: The form of the ozone design value is the 4th highest daily 8-hour maximum concentration (D8M), averaged over three years. The 5-year 98th percentile (2010–2014) D8M was calculated as a surrogate for the design value for several reasons:

1. The 5-year 98th percentile represents the five years of data collected since the previous network assessment (2010–2014).
2. The 98th percentile D8M is equivalent to the 4th high D8M in years with complete data. Using the 98th percentile rather than the 4th high in years with only partial data completeness minimizes bias from missing data.
3. The 4th highest daily D8Ms are highly variable from year to year. The 98th percentile of a full five years of data is a more stable metric that approximates the mid-range of three years of design values at a given site.

Sites with the highest 98th percentile D8Ms were given the highest scores.

75th percentile

Purpose: While the 98th percentile D8M represents ozone concentrations on highest days in the ozone season, the 75th percentile is a better representation of ozone concentrations on typical days. The distribution of ozone concentrations at a given site varies by region and topography. Sites with high design values may report relatively low concentrations on typical days, while sites that routinely report relatively elevated concentrations may never reach unhealthy concentrations on their worst days. The 75th percentile D8M provides information on chronic levels of exposure to ozone over the long-term.

Methods: The 5-year 75th percentile D8M was calculated at each site. Sites with the highest 75th percentile D8Ms were given the highest scores.

Days over 65 ppb

Purpose: EPA plans to issue a revised 8-hour ozone standard in late 2015. The proposed range for the standard is between 65 and 70 ppb. Frequent exceedances of 65 ppb indicate a higher risk of violating an 8-hour ozone NAAQS at the low end of this range. As adverse health effects of ozone exposure have been documented at concentrations as low as 65 ppb (US EPA, 2013), a large percentage of sample days above this threshold also indicates a greater risk of health impacts from impaired air quality.

Methods: The number of D8Ms over 65.4 ppb were divided by the number of total valid D8Ms over the 5-year period (2010–2014). Sites with the highest percentages of days over 65.4 ppb were given the highest scores.

Probability of a single day over 70 ppb

Purpose: EPA plans to issue a revised 8-hour ozone standard in late 2015. The proposed range for the standard is between 65 and 70 ppb. Frequent exceedances of 70 ppb indicate a higher risk of violating an 8-hour ozone NAAQS in the upper end of this range.

Methods: Maximum likelihood estimation methods were applied to the highest four D8Ms per year at each site to yield the probability of a single D8M over 70 ppb in a given year. Sites with the highest probability of an exceedance of this threshold were given the highest scores.

Trend

Purpose: Sites at which concentrations are rising rapidly are potential targets for more intensive monitoring and/or interventions to reduce emissions. Sites at which concentrations are declining rapidly are potential targets for less intensive monitoring.

Methods: The trends in deseasonalized 98th and 75th percentile maximum daily 8-hour averages were computed as ppb/year. The absolute values of the two trends were then normalized and summed. Sites with the largest absolute value trends were given the highest scores.

Population served

Purpose: Monitors in dense population centers provide information on the exposures of a large number of people. As ozone formation is a complex process involving a mix of regional sources, monitoring sites do not simply represent the geographic areas and populations closest to them. The population of the surrounding core-based statistical area (CBSA) was attributed to each monitoring site in order to reflect the regional nature of ozone formation and transport.

Methods: CBSA boundaries were obtained from the U.S. Office of Management and Budget. Where monitoring sites were located within both Metropolitan Statistical Areas (MSAs) and Combined Statistical Areas (CSAs), they were given the attributes of the CSA populations. Sites with the highest CBSA populations represented were given the highest scores.

Population growth

Purpose: Monitors in areas of rapid population growth are of particular interest because concentrations may rise in tandem with growth and development. These sites may be candidates for more intensive monitoring in the future.

Methods: The population living within each monitor's associated CBSA was extracted from the 2010 and 2000 censuses. The population growth rate was calculated as the rate of change in population between the decennial censuses. Sites whose associated CBSAs had the highest rates of population growth were given the highest scores.

Environmental justice index

Purpose: Ecology is committed to protecting the residents of Washington State from environmental and health hazards without regard to race, income, education, culture, national origin, or other demographic factor. Central to Ecology's commitment to environmental justice is the equitable provision of services among the state's demographic groups. Low-income and communities of color typically face higher burdens of environmental pollution and greater susceptibility to environmental health hazards, including air pollution. In light of this, environmental justice is an important consideration in the distribution of monitoring resources. Monitoring sites in communities with environmental justice concerns provide additional value to the network on the air pollution exposures of historically under-represented and under-served populations.

Methods: Four socioeconomic indicators were extracted from the 2013 5-year American Community Survey within each monitor's associated CBSA:

1. Linguistic isolation (percent of households without a member who speaks English "very well" or better)
2. Low educational attainment (percent of individuals 25 years and older without a high school diploma or equivalent)
3. Poverty (percent of individuals living below 200 percent of the federal poverty level for their household size)
4. Unemployment (percent of the civilian work force both eligible and unemployed)

Percentages for each indicator were normalized to a scale of 0–10 and summed. This method of tabulating environmental justice scores was developed by the California Office of Environmental Health Hazards (OEHHA, 2014). Sites with the highest percentages in each socioeconomic category were given the highest scores.

Error between AIRPACT model and monitor

Purpose: The Air Indicator Report for Public Awareness and Community Tracking (AIRPACT) model provides daily air quality forecasts for the Pacific Northwest. Model performance varies across the state and is often dependent on meteorological conditions. In areas with poor model performance, monitoring data provides additional value because model predictions are less accurate. In addition, these monitors also provide researchers with crucial data to assess and subsequently improve model performance.

Methods: Fractional bias (FB) was calculated by comparing model predictions to monitored values at each site using the following equation:

$$FB = \frac{1}{N}\sum_{i=1}^{N}\frac{(C_m - C_o)}{\left(\frac{C_o + C_m}{2}\right)}$$

Where:

C_m is the modeled daily mean $PM_{2.5}$ concentration
C_o is the observed daily mean $PM_{2.5}$ concentration
N is the number of days when both measurements were available for comparison

Sites with the highest FB (poorest model performance) were given the highest scores.

Evaluating Redundant O_3 sites

Of all the ozone sites in Washington, three are clustered in close proximity and their redundancy was investigated. The site at Augusta Ave in downtown Spokane is located at the SRCAA office, and has been operating during the ozone season since 2009. The site in Cheney lies about 25 miles to the southwest of Spokane and about four miles east of I-90. The site at Greenbluff lies about 13 miles to the northeast. The latter two sites have been operating for over 15 years. Previous work had shown that elevated ozone levels could occur during southwest or northeast winds, thereby impacting Greenbluff or Cheney, respectively. Data from the Augusta Ave site was analyzed to see if it offered additional information not captured by the other two sites.

Figure 19 shows how the number of high ozone days (with a daily 8-hour maximum [D8M] of over 60 ppb; excluding days with obvious wildfire impacts) recorded at each of the three sites compare. It appears that the Augusta Ave site does not record substantially higher values any more frequently than the other sites.

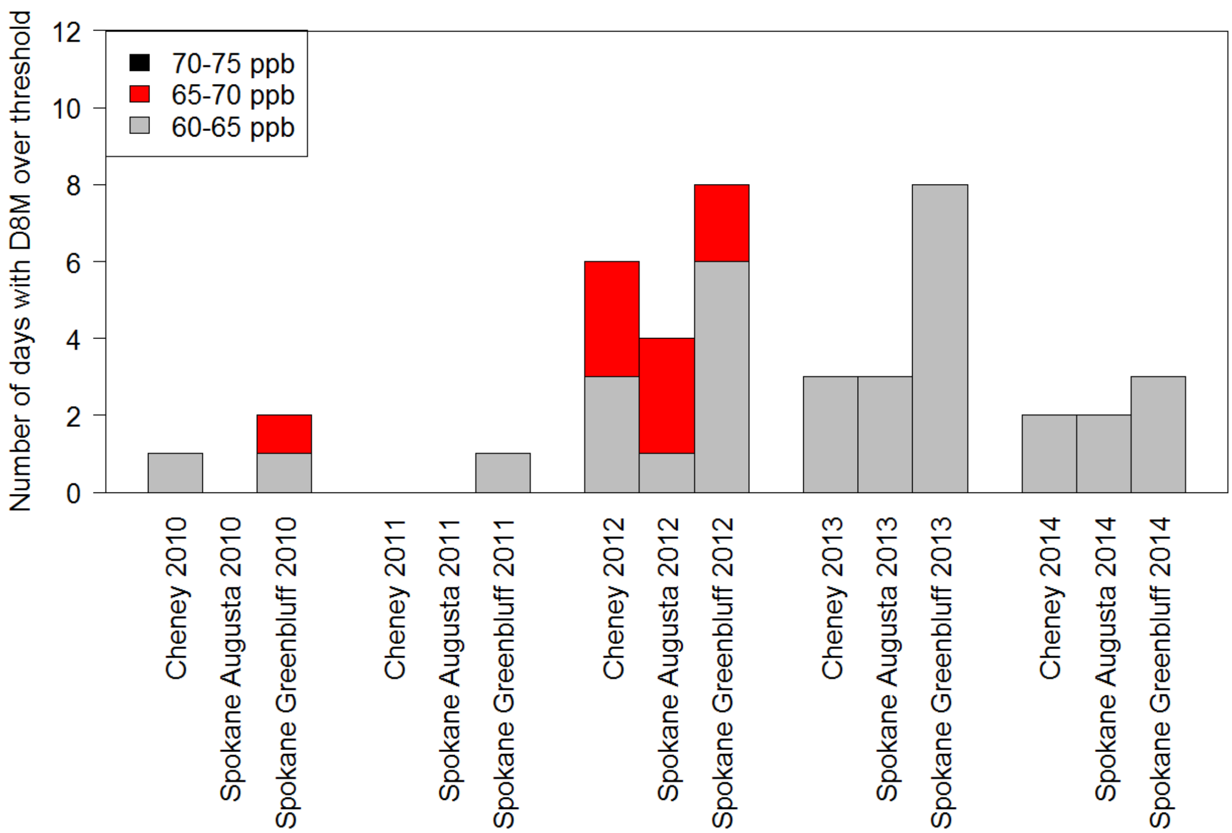


Figure 19. Comparison of high ozone days at Spokane area sites from 2010–2014

Diurnal profiles are compared in Figure 20 by box plotting the differences of hourly concentrations. The left and right panels show that Greenbluff ozone levels are higher than both Cheney and Augusta at night, although overall ozone levels are low at these times of day. This is suggestive of NO_X titration at both Augusta and Cheney and the lack thereof at Greenbluff. City traffic would produce sufficient NO_x to titrate evening O_3 at Augusta, and the NO_X titration at

Cheney is thought to occur because of a directional shift of summertime evening winds. Light east- northeast winds develop through the evening and night and could transport NO_X from Spokane as well as portions of I-90, to Cheney and suppress O_3. No substantial NO_X sources lie upwind of Greenbluff under this flow pattern, resulting in little O_3 titration there.

During daylight hours when ozone levels are at their highest, including summertime evenings, Greenbluff runs slightly higher than Augusta and Cheney more than 50 percent of the time. This is shown by the medians lying below the zero (green) line between 9AM and 6PM.

The center panel of Figure 20 shows Cheney and Augusta with similar diurnal ozone profiles, though Cheney is usually higher. There is also a little extra NO_X titration during the morning rush hour at Augusta.

Taken together, there appears to be minimal additional information gained from running the ozone site at Augusta Avenue. Salient features of the diurnal cycle and the highest D8Ms are sufficiently well captured by the other two Spokane area sites. This site has operated for six successive ozone seasons and is yet to record information that would have been unknown but for its presence.

Recommendation

- Discontinue ozone monitoring at Spokane- Augusta Ave. site.

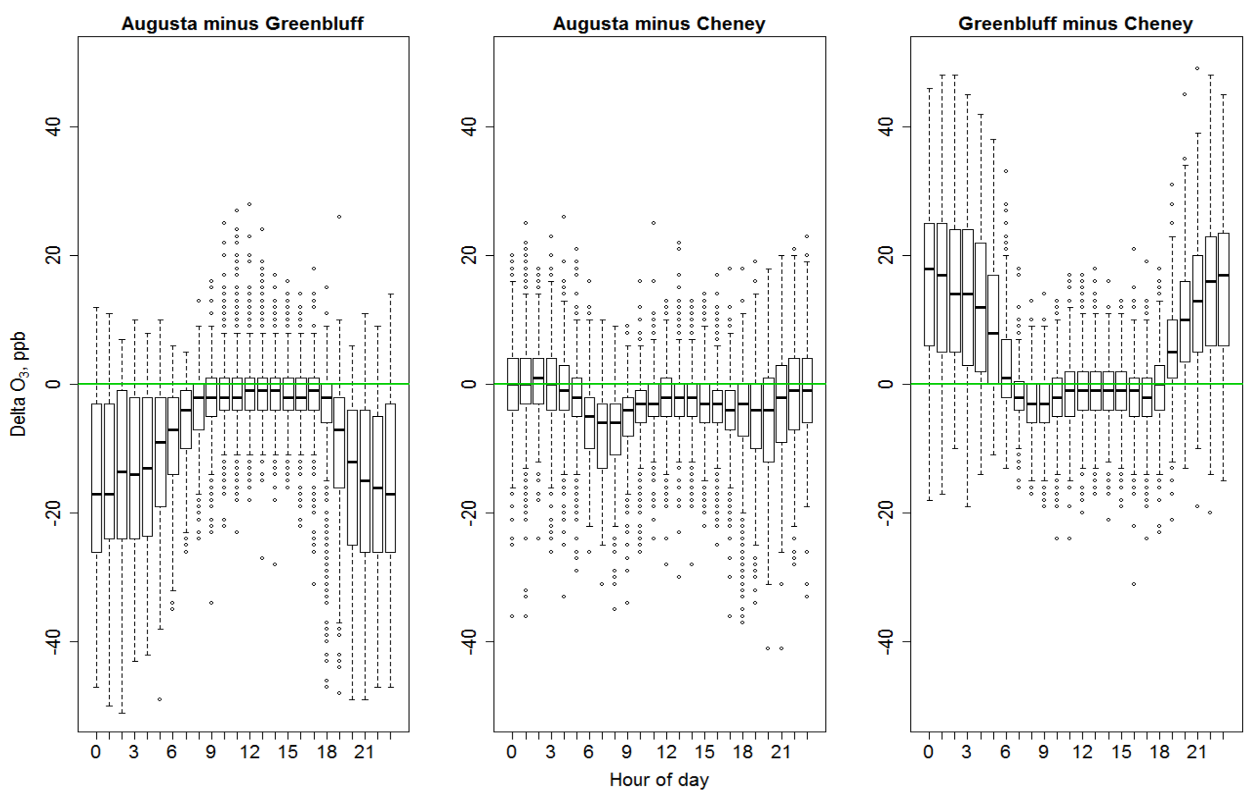


Figure 20. Boxplots of hourly ozone concentration differences at Spokane area sites

Investigation of Ozone Hotspot in Kennewick

As stated earlier, an ozone hotspot was predicted by the 4 km Airpact model and subsequently verified with a temporary monitor in Kennewick. Although sufficient data do not yet exist for calculating design values, the 98th percentile concentrations are in the upper 60's. Much analysis was done using Airpact model data, meteorological data, historical NO_X and current O_3 data from Hermiston, OR. The Hermiston site does not serve as a suitable substitute for ozone in Kennewick.

Figure 21 shows pollution roses of ozone (only considering hours > 60ppb) at Kennewick and Hermiston. High ozone is coincident with mild to moderate (mostly <6 mph) north-northeast winds and temperatures > 85°F. Kennewick records slightly higher ozone concentrations than Hermiston does, and there is a notable absence of high ozone valued during west winds at Kennewick. The north- northeast wind flow is expected to be conducive to ozone formation by damming up ozone precursors against the Horse Heaven hills. The spatial extent and the sources of ozone precursors around Kennewick need to be investigated.

Recommendation

- Establish permanent ozone monitoring in Kennewick.

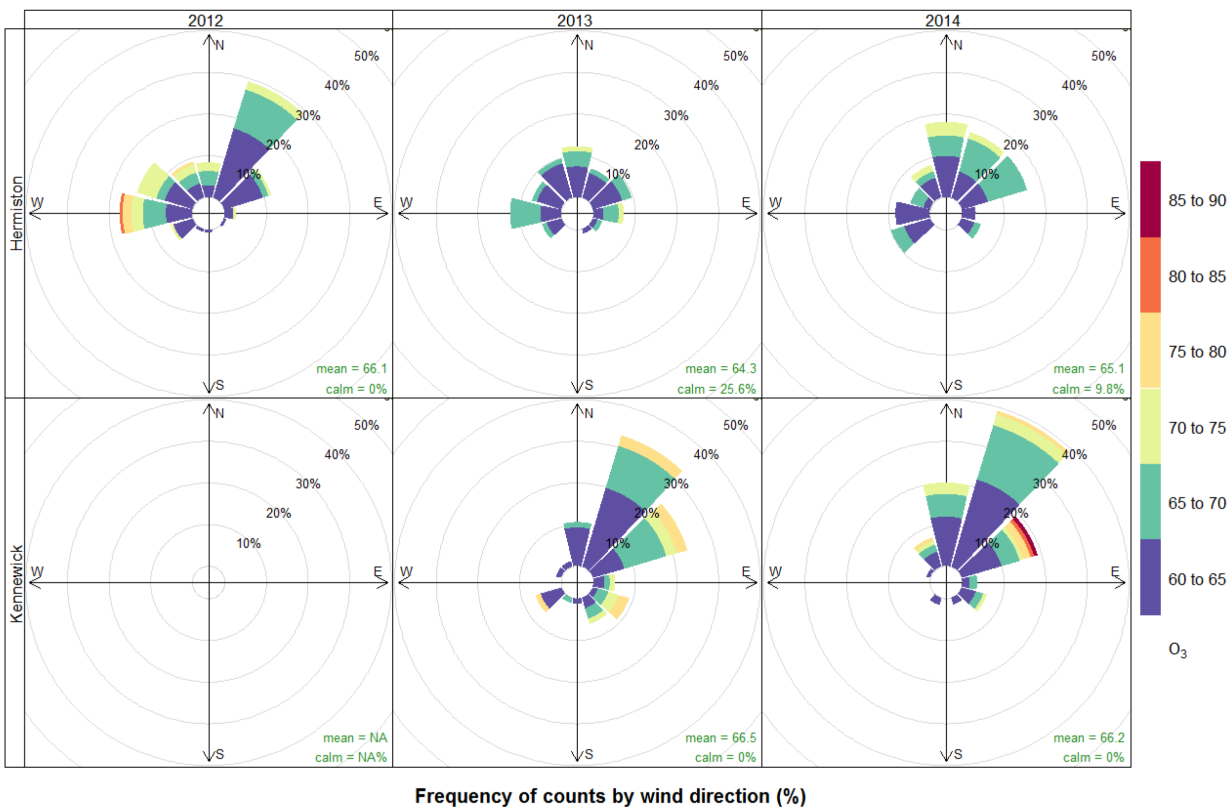


Figure 21. Comparing last three ozone seasons at Hermiston and Kennewick: hours > 60 ppb only

PM_{10}

In 1990, there were seven PM_{10} nonattainment areas in Washington State, all of which are now maintenance areas as concentrations have decreased due in part to successful control strategies. As a result of declining values and a greater emphasis on fine particles, Ecology has transitioned away from PM_{10} monitoring on a wide scale. While PM_{10} concentrations have decreased over the years and PM_{10} is thought to represent less of a health risk than fine particles, short-term exposure remains a serious threat to human health. For this reason, EPA has maintained the 24-hour NAAQS of 150 $\mu g/m^3$ and Ecology continues to monitor PM_{10} in a few locations that experience occasionally elevated concentrations due primarily to windblown episodes.

Ecology and its partners currently operate and maintain four PM_{10} monitors as part of the Washington ambient air quality network. One of these monitors is filter-based (manual) FRM PM_{10} samplers and three are continuous TEOM instruments. The manual and continuous method PM_{10} network primarily serves to meet PM_{10} monitoring requirements in maintenance areas [Spokane, Wallula (Kennewick) and Yakima] as well as provide information for public health protection during episodes of windblown dust in the Columbia basin. All monitors are located in Eastern Washington. Table 6 presents the monitor locations, monitor types, and frequency of operation.

Ecology did not use a decision matrix nor conduct any spatial analyses to evaluate its PM_{10} network because the small number of monitors.

Table 8. Washington State PM_{10} Monitoring Network

Station Name	Instrument	Sampling Frequency
Colville-Oak St. S.	TEOM	Continuous
Kennewick-Metaline St	TEOM	Continuous
Spokane-Augusta Ave.	TEOM	Continuous
Yakima-4th Ave.	FRM	1/6

It should be noted that in contrast to $PM_{2.5}$, wood smoke in Washington does not result in PM_{10} levels close to the PM_{10} NAAQS. With the exception of Colville, all of the 24-hour PM_{10} standard exceedances measured at these stations in the last three years are attributable to high winds and resultant windblown dust. High winds, a natural event, and the primary driver of high PM_{10} concentrations at most of the stations, generate dust storms that occur occasionally in Eastern Washington. The PM_{10} network generally addresses monitoring needs as they relate to Ecology's goal and objectives, and therefore, most of it should be retained. The exception (Yakima) is discussed in greater detail below.

PM_{10} FRM at Yakima

The PM_{10} FRM sampler at Yakima runs on a 1-in-6 days schedule has been operating for 15 years, mostly in fulfillment of the Yakima PM_{10} maintenance plan. This is the only FRM PM_{10} sampler in the network and carries a substantial operational burden and cost. Since 2000, the highest value recorded by this sampler was 103 $\mu g/m^3$; it has not recorded a concentration over

75 µg/m³ (i.e., half the PM_{10} NAAQS) since February 2005. A $PM_{2.5}$ FRM and $PM_{2.5}$ FEM TEOM sampler have been collocated since May 2000 and October 2011, respectively. Ecology plans to request that EPA approve discontinuance of the PM_{10} FRM, in light of a sufficiently stringent $PM_{2.5}$-PM_{10} correlation. EPA approved a SIP revision for the Thurston County PM_{10} Limited Maintenance Plan[1] in 2013, where a nephelometer served as a proxy for PM_{10} and the Kent, Seattle and Tacoma Limited Maintenance plan for PM_{10} in 2013[2] also features PM_{10} correlations based on FEM TEOM $PM_{2.5}$ data.

Figure 22 shows a plot of PM_{10} vs. $PM_{2.5}$ and overlays trendlines from Ordinary Least Squares (OLS) regression and robust regression using repeated medians. (R^2 only applies to OLS and not to robust regression methods). Robust regression methods are less sensitive to the presence of a few outliers.

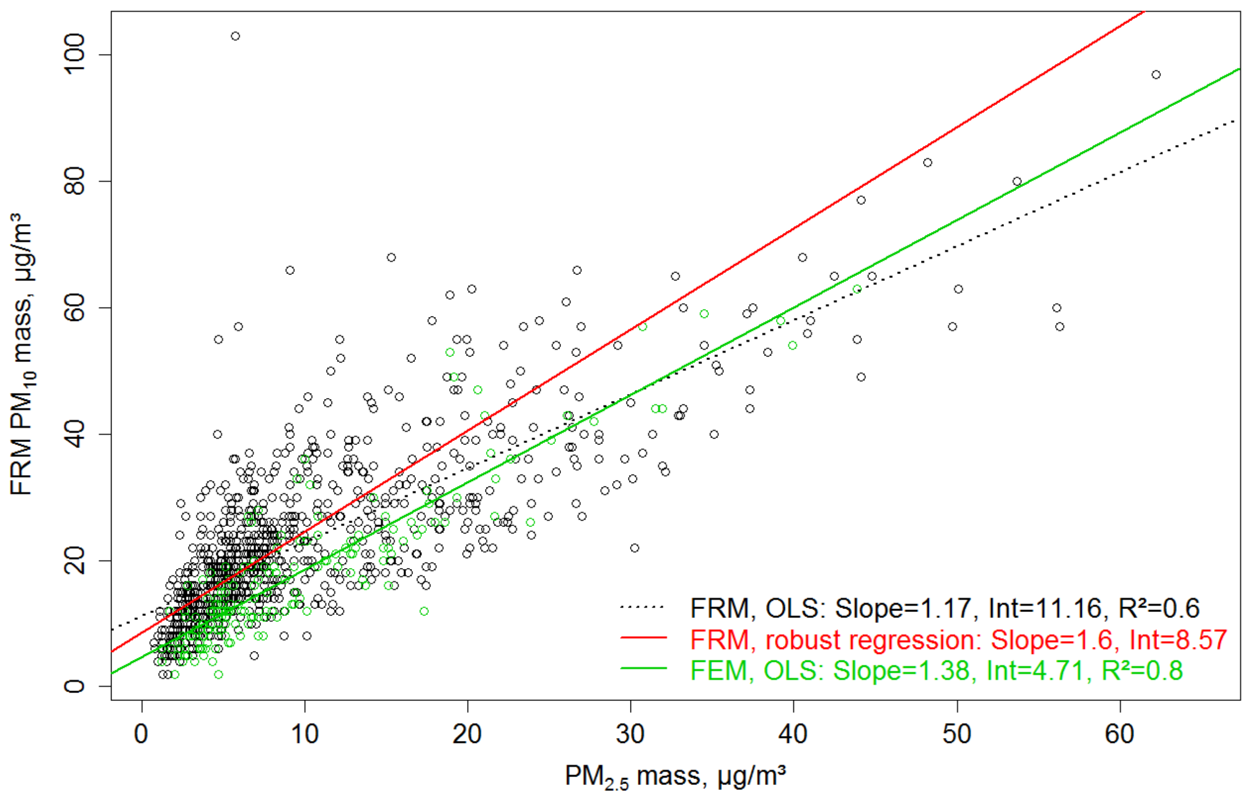


Figure 22. PM_{10} vs. $PM_{2.5}$ in Yakima

High PM_{10} levels often coincide with low $PM_{2.5}$ levels, suggesting large amounts of coarse material. However the last time PM_{10} concentrations over 60 µg/m³ coincided with $PM_{2.5}$ levels under 10µg/m³ was in July 2004. Since then, PM_{10} levels in excess of 40µg/m³ mostly occurred between October and March, when $PM_{2.5}$ levels were also elevated mostly due to wood smoke. All but one of the four exceptions after 2004 occurred on days impacted by wildfire smoke.

1 https://fortress.wa.gov/ecy/publications/documents/1302008.pdf
2 http://www.ecy.wa.gov/programs/air/sips/pdfs/PM10-LMP_Draft-Kent_Seattle_Tacoma.pdf

The reasons behind reduction in coarse mass after 2004 are beyond the scope of this document. Only data from the 10-year period of 2005–2014 are considered henceforth. The $PM_{2.5}$ FRM sampler was not operated in Yakima from January 2005 through January 2007. However substituting nephelometer $PM_{2.5}$ data collecting during this period did not alter regression coefficients by more than a few percent.

Figure 23 shows how the relationship between $PM_{2.5}$ and PM_{10} varies by season. The steepest slopes (i.e., more PM_{10} per µg of $PM_{2.5}$) occur in the spring months when PM_{10} concentrations are low. Moderate slopes occur in the summer through early fall when dry conditions are conducive for blowing dust, and wildfire smoke also impacts the area. $PM_{10}/PM_{2.5}$ ratios are the lowest in winter when most of the PM_{10} comprises of fine particles from wood burning.

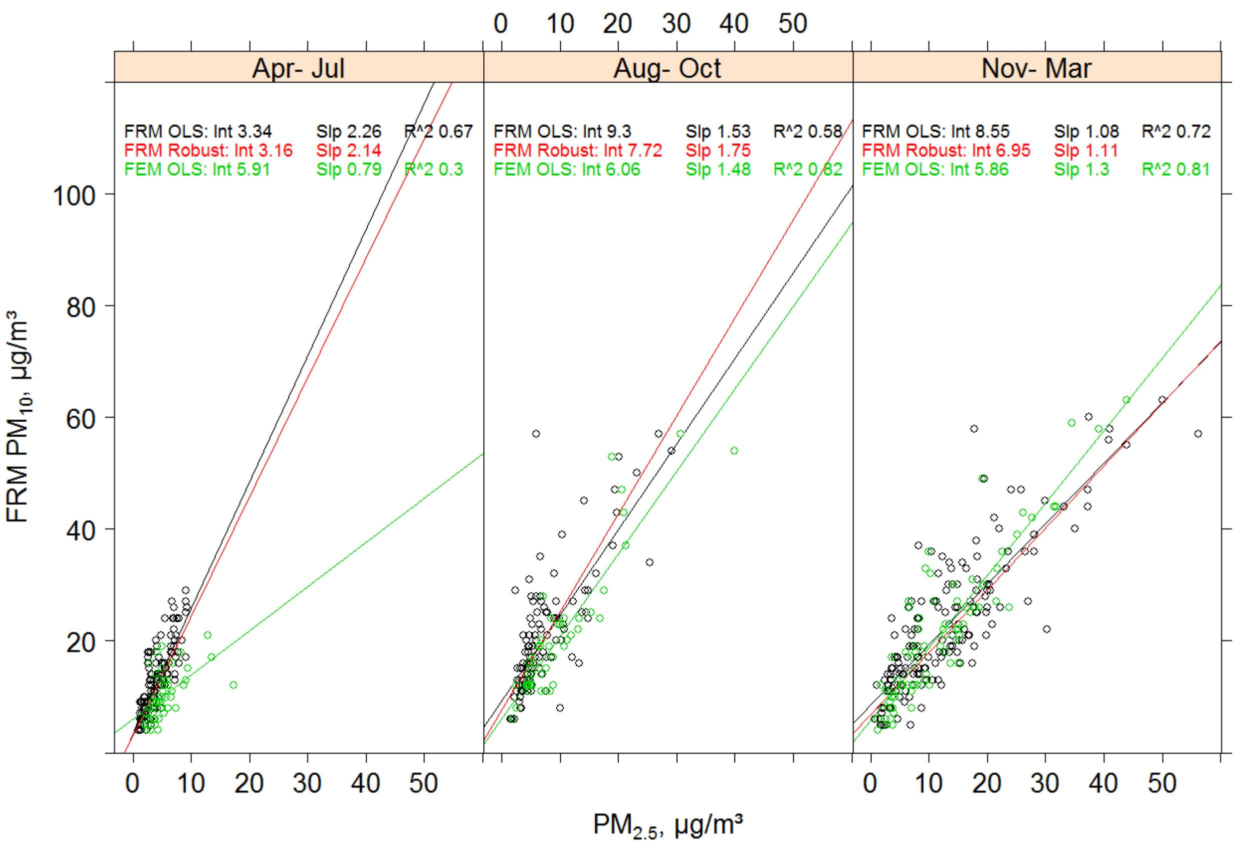


Figure 23. Seasonal relationship between PM_{10} and $PM_{2.5}$ in the last 10 years

The most conservative seasonal regression coefficients from Figure 23 were used with measured $PM_{2.5}$ to reconstruct PM_{10} and compare with the measured PM_{10}. The quantile- quantile plot in Figure 24 shows that reconstructed PM_{10} is distributed higher than the measured PM_{10} data, suggesting the correlation is consistently conservative.

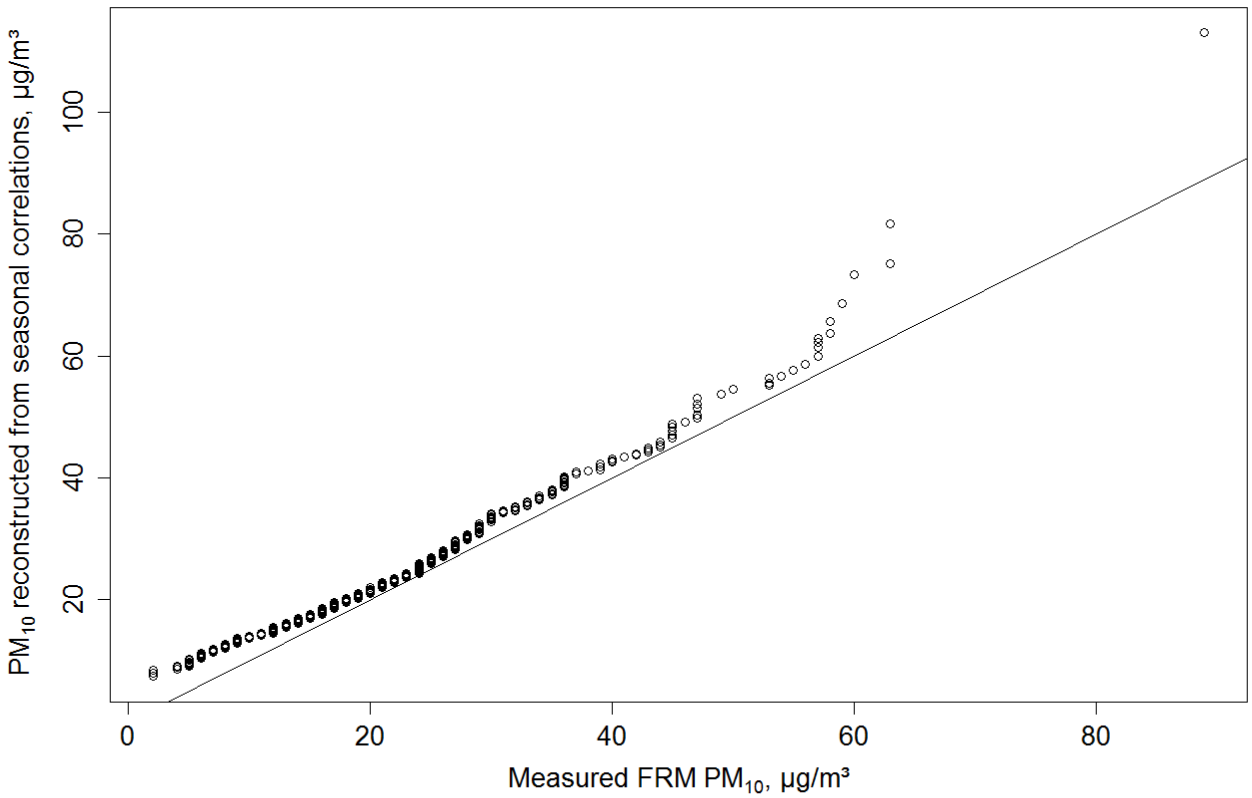


Figure 24. Quantile- quantile plot for checking reconstructed PM_{10} against measured PM_{10} in Yakima, 2005–2014

Of the $PM_{2.5}$ samplers, the FRM is more likely to be discontinued in the coming years (although no such plans are final at this time), leaving the FEM in place. The R^2 value of the PM_{10} FRM vs. $PM_{2.5}$ FEM exceeds the EPA criteria of 0.7 (Figure 22 and Figure 23; although R^2 is low during the spring months, PM_{10} levels are low during this time), and has the added benefit of providing near real time estimates of PM_{10}, rather than having to wait about two months for results from filter-based gravimetric methods.

Recommendation

- Discontinue PM_{10} FRM sampler in Yakima; replace with more stringent estimate based on $PM_{2.5}$ FEM measurements using the formula below

- PM_{10}, µg/m³ = In April- July, $PM_{2.5}$ * 2.26 + 5.91;
  In August- October, $PM_{2.5}$ * 1.75 + 9.3;
  In November- March, $PM_{2.5}$ * 1.3 + 8.55

Carbon Monoxide

As of December 31, 2014, Ecology operated one CO monitor at Spokane-3rd St. S. as part of the Washington ambient air quality network. As a result of control strategies and the gradual replacement of older vehicles with less-polluting ones, CO pollution levels have fallen dramatically in Washington State over the last two decades and are now far below the NAAQS. In addition, CO levels are expected to continue to fall as new vehicles being sold in Washington meet some of the strictest emission standards in the U.S.

For these reasons, Ecology and its partners have divested of CO monitoring and will continue to do so in favor of other emergent monitoring gaps and needs.
Recommendation:

- Ecology will request that this last CO monitor be removed when Spokane's 2nd 10-year maintenance plan is submitted.

Other Monitoring Projects Conducted Since 2010

Yakima Air Winter Nitrate Study (YAWNS)[3]

The 2010 monitoring network assessment report discussed an area of elevated aerosol nitrate in the Columbia Basin. On days with high $PM_{2.5}$ levels, up to a quarter of Yakima's $PM_{2.5}$ consisted of nitrate- more than other parts of the state. Ecology contracted with Washington State University (WSU) and Central Washington University (CWU) to identify the source categories and conditions under which elevated nitrate occur. Three weeks of intensive sampling was conducted in January 2013. Main findings were:

- The most likely cause of high nitrate levels is ammonia from agricultural activities interacting with oxides of nitrogen from motor vehicles during the right weather conditions.
- It is unlikely that there is much transport of pollutants between the upper and lower Yakima valleys during stagnant periods.
- The pathway to reducing aerosol nitrate is not obvious. Reductions in NO_X could in fact increase aerosol nitrate, due to the nature of the atmospheric chemical processes. A modeling study is needed to determine the exact response of the airshed. The YAWNS study provided several valuable inputs to such a study.

Preventing Nonattainment

In 2013, the state legislature provided funds for a pilot project in a central Washington community to prevent nonattainment through proactive actions. Ellensburg was selected and a Clean Air Task Force was formed with stakeholders from the Kittitas County Public Health Department, Central Washington University, the City of Ellensburg, nonprofit organizations and other public agencies. This task force worked to raise community awareness and reduce $PM_{2.5}$

[3] http://www.ecy.wa.gov/programs/air/air_monitoring_data/PDFs/Yakima_Air_Winter_Study_Report.pdf

emissions. Portable monitors were used to map out the spatial variability of $PM_{2.5}$ around the city. CWU researchers are also working on developing a vertical temperature profile of the Kittitas valley (an indication of meteorological stability and a forecasting tool), and testing low cost portable monitors for other pollutants.

Findings and Recommendations

Overall, the Washington State ambient air monitoring network is efficient and effective at meeting the monitoring policy goal and objectives. Therefore, wholesale network changes are not necessary. However, several specific, targeted changes will improve overall network effectiveness.

If resource savings are achieved through improvements in network efficiency, they should be reinvested to address monitoring gaps and high priority future monitoring requirements:

CO:

Discontinue Spokane-3rd St. S. station – While this is a Maintenance Plan/SIP required site, the data from this monitor is well below the NAAQS, is of little value, and resources could best be used for higher priority monitoring.

PM_{10}:

Discontinue Yakima-4th Ave. monitor – While this is a Maintenance Plan/SIP-required site, the data from this monitor is well below the NAAQS, is of little value, and resources could best be used for higher priority monitoring. A proxy correlation based on $PM_{2.5}$ data, is proposed.

$PM_{2.5}$:

Discontinue nephelometer monitoring at the following sites:

- **Tulalip** – This airshed is sufficiently represented by the Marysville monitor.
- **Oakville** – The Chehalis monitor serves as a conservative proxy for $PM_{2.5}$ monitoring in Oakville.

Replace compliance monitors with FEM BAMs at key monitoring sites:

- **Spokane-Augusta Ave.** – Replace the FRM and FEM TEOM with a FEM BAM.
- **Yakima-4th Ave.** – Replace the FEM TEOM with a FEM BAM. The FRM should be retained to meet collocation requirements for FEM BAMs.
- **Vancouver-NE 84th Ave.** – Replace the FEM TEOM with a FEM BAM.

Ozone:

Investigate sources of ozone precursors in Kennewick.

Discontinue the Spokane Augusta ozone monitor– This site is well represented by the Cheney and Spokane Greenbluff sites.

Meteorological:

Install meteorological monitoring at the Yakima $PM_{2.5}$ site.

Of the top ten most important sites shown in the PM2.5 section (Figure 5), Yakima is the only site without collocated meteorological measurements. Meteorological data are needed for air quality management, forecasting, and data analysis. The current practice is to utilize wind data collected at the nearby Yakima airport. However winds at airports are reported as calm when speeds drop below 3 knots (3.45 mph), as these low winds do not interfere with aviation. Unfortunately this is also the range of speeds that are most critical for air quality management. Forecasting and data analysis efforts will benefit substantially if meteorological measurements not subject to this 3 knot limitation are made on-site.

Wherever practical, resource-savings obtained from discontinuing monitors/stations should be reinvested in order to address the monitoring data gaps described above.

As funding or resources are available, prioritize which new federal monitoring requirements will be implemented. Forthcoming requirements include those associated with the EPA rule revision for NO_2 and potential new requirements for ozone, SO_2, and Pb EPA is reviewing over the next five years.

Acronyms, Abbreviations, and Terms

AQI	U.S. Environmental Protection Agency's Air Quality Index
BAM	Beta Attenuation Monitor
bscat	Measurement of Light Backscatter
CMAQ	Community Multi-Scale Air Quality model
CO	Carbon monoxide
CSN	Chemical Speciation Network
EBAM	Environmental Beta Attenuation Monitor
EC	Elemental carbon
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
IMPROVE	Interagency Monitoring of Protected Visual Environments
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standard(s)
NATTS	National Air Toxics Trends Station
NCore	National Core Monitoring
NH_4NO_3	Ammonium nitrate
NO	Nitric oxide
NO_2	Nitrogen dioxides
NO_3^-	Nitrate ion
NO_x	Nitrogen oxides
NO_Y	Reactive oxides of nitrogen
non-FRM	Non-Federal Reference Method
OC	Organic carbon
PAH	Polycyclic Aromatic Hydrocarbons
PAMS	Photochemical Air Monitoring Station
PM	Particulate matter
$PM_{2.5}$	Fine Particles or particulate matter with an aerodynamic diameter of 2.5 microns or less
$PM_{10-2.5}$	Coarse particles or particulate matter with an aerodynamic diameter between 10 and 2.5 microns
PM_{10}	Particulate matter with an aerodynamic diameter of 10 microns or more
ppm	Parts per million
PSD	Prevention of Significant Deterioration
SO_2	Sulfur dioxide
SO_4^{2}	Sulfate ion
TEOM	Tapered Elemental Oscillating Microbalance
TSP	Total Suspended Particulate
VOC	Volatile organic compound
WAQA	Washington Air Quality Advisory

References

Desert Research Institute (DRI), 2010, "Climate of Washington," <http://www.wrcc.dri.edu/narratives/WASHINGTON.htm>, accessed May 19, 2010.

Hopke et al., (2006), Analyses of PM-Related Measurements for the Impacts of Ships, available at <http://www.arb.ca.gov/research/seca/hopkefr.pdf> , accessed May 19, 2010.

Kim, E and Hopke, PK, (2008), Source characterization of ambient fine particles at multiple sites in the Seattle area, Atmospheric Environment, 42(24), 6047-6056.

Naeher et al., (2007), Wood smoke Health Effects: A Review, Inhalation Toxicology, 19 (1), 67-106.

Office of Environmental Health Hazard Assessment, 2014, California Communities Environmental Health Screening Tool, Version 2.0, available at <http://oehha.ca.gov/ej/pdf/CES20FinalReportUpdateOct2014.pdf >, accessed May 11, 2015.

US Census Bureau, 2010, Census 2010, Summary File 1, generated using American FactFinder, available at <http://factfinder2.census.gov/>, accessed April 1, 2015.

US Census Bureau, 2013, American Community Survey (2009–2013), generated using American FactFinder, available at <http://factfinder2.census.gov/>, accessed April 1, 2015.

US EPA, 2002, Data Quality Objectives (DQOs) for Relating Federal Reference Method (FRM) and Continuous $PM_{2.5}$ Measurements to Report an Air Quality Index (AQI), available at <http://www.epa.gov/ttnamti1/files/ambient/monitorstrat/aqidqor2.pdf>, accessed May 18, 2015.

US EPA, 2013, Integrated Science Assessment of Ozone and Related Photochemical Oxidants, EPA/600/R-10/076F, available at <http://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492>, accessed May 11, 2015.

US EPA, 2015, Program Update: Airport Lead Monitoring, EPA-420-F-13-032, June 2013, available at <http://www.epa.gov/otaq/regs/nonroad/aviation/420f13032.pdf>, accessed May 18, 2015.

WA Dept of Ecology, 2010, Sources of Fine Particles in the Wapato Hills-Puyallup River Valley $PM_{2.5}$ Nonattainment Area, available at <http://www.ecy.wa.gov/pubs/1002009.pdf>, accessed May 19, 2010.

Wu et al., (2006), Source Apportionment of Seattle and Portland Air Toxics and $PM_{2.5}$ Data, available at <http://www.epa.gov/ttnamti1/files/ambient/airtox/rgirept.pdf>, accessed May 19, 2010.

Appendices

Appendix A. $PM_{2.5}$ Decision Matrix Results

Results of the $PM_{2.5}$ decision matrix are shown in the tables below. Table 9 is a guide for the column headings of the remaining tables.

Table 9. Decision Matrix Result Table Column Headings

Criteria	Column Heading
24-hour design value	A
Annual design value	B
Days > 20	C
Probability of exceedance	D
98th percentile trend	E
Annual mean trend	F
Population served	G
Population growth	H
Environmental justice	I
Point sources	J
Smoke impacts	K
Traffic density	L
Acres burned	M
Geographic area served	N
AIRPACT model/monitor error	O
Forecasting value	P

Table 10. $PM_{2.5}$ Decision Matrix Results (raw data)

Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Aberdeen-Division St	13.00	4.62	0.00	0	0.95	0.32	31049	0.03	14.80	216.07	0.00	264298	0	138.66	44.70	1
Anacortes 202 Avenue	13.77	6.75	0.00	0	1.43	1.12	26427	0.10	4.54	98.39	0.00	110877	0	392.27	19.30	0
Bellingham-Yew St	15.46	5.98	0.00	0	1.03	0.36	125587	0.19	9.00	103.23	0.00	572505	0	296.32	59.90	1
Bellevue-Bellevue Way	12.92	4.77	0.00	0	0.49	0.27	438508	0.18	3.94	54.14	0.00	2956845	0	254.01	50.10	0
Bremerton-Spruce Ave	12.13	4.74	0.00	4	1.03	0.29	266466	0.09	6.00	17.93	0.00	568708	0	520.13	42.80	3
Cheeka Peak	5.85	2.26	0.00	2	0.12	0.04	8101	-0.04	12.38	0.00	0.00	0	0	962.90	0.00	0
Chehalis-Market Blvd	16.32	6.04	0.01	0	0.42	0.27	70329	0.14	12.58	83.70	0.00	591588	0	656.83	1.04	1
Clarkston-13th St	25.77	8.14	0.04	7	0.73	0.32	20916	0.05	8.53	125.76	0.00	73428	667	125.23	96.20	3
Colville-Oak St S	25.26	9.06	0.06	5	0.20	-0.08	16427	0.00	10.52	22.87	0.00	89903	52	504.41	107.00	3
Darrington-Fir St	28.21	6.81	0.06	89	0.44	-0.23	2381	0.14	8.07	7.20	0.00	22480	0	121.92	122.00	3
Dayton-W Main St	14.71	5.35	0.00	0	0.12	0.06	7461	-0.01	8.87	0.00	0.00	30433	26493	1374.62	20.90	2
Ellensburg-Ruby St	29.61	7.30	0.06	77	0.08	-0.04	29703	0.23	12.48	2.05	0.00	226130	161	241.53	85.80	3
Kennewick-Metaline	18.84	6.21	0.01	0	0.08	0.03	233929	0.33	12.03	5.91	0.00	866605	0	1709.44	34.00	3
Kent-Central & James	22.63	7.00	0.03	47	-0.14	-0.67	450808	0.15	10.49	79.67	0.00	2817081	0	226.33	31.10	3
Lacey-College St	25.20	6.53	0.04	85	1.31	0.69	200362	0.19	7.01	1.93	0.00	985101	0	343.01	21.60	3
LaCrosse-Hill St	13.64	4.31	0.00	0	0.60	0.19	1763	-0.27	5.03	0.01	0.00	10633	35396	1229.90	27.20	2
Leavenworth-Evans St	26.09	7.87	0.05	8	1.94	0.67	9513	0.03	8.04	0.07	0.00	91967	112	264.56	105.00	3
Lake Forest Park-Town Center	23.40	7.38	0.04	21	0.27	0.07	352521	0.10	4.87	24.02	0.00	2093876	0	118.59	18.30	2
Longview-30th Ave	16.76	5.52	0.01	0	0.59	0.40	92249	0.08	12.55	132.79	0.00	533850	0	407.73	8.66	3
Lynnwood-212 (ULT)	21.42	6.24	0.02	1	0.45	0.20	300097	0.13	8.79	10.60	0.00	2252047	0	118.70	40.80	3
Mesa-Pepiot Way	17.85	5.85	0.01	2	0.06	0.01	24432	0.17	27.59	0.87	0.00	105017	3976	1428.78	33.80	2
Moses Lake-Balsam St	18.90	6.29	0.02	0	0.51	0.18	71784	0.16	18.30	2.90	0.00	267132	6490	3004.31	57.70	3
Marysville-7th Ave	25.52	7.69	0.04	61	0.45	0.30	182217	0.16	9.04	13.90	0.00	1231727	0	125.88	0.97	3

Table 10. $PM_{2.5}$ Decision Matrix Results (raw data)

Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Mt Vernon-S Second St	10.37	4.42	0.00	0	0.00	-0.10	94284	0.16	10.57	39.73	0.00	658961	0	602.23	5.17	2
North Bend-North Bend Way	14.99	5.42	0.01	8	0.22	0.16	61425	0.25	2.97	0.02	0.00	381938	0	618.54	3.19	3
Neah Bay 2-Makah Tribe	8.49	3.68	0.00	0	0.47	0.33	1549	-0.09	15.12		0.00	1543	0	262.32	88.70	0
Oakville-Chehalis Tribe	15.19	4.68	0.00	0	1.35	0.59	23228	0.20	9.68	4.51	0.00	47064	0	432.43	14.10	1
Omak-Colville Tribe	30.38	8.61	0.07	92	0.71	0.35	10033	0.02	10.58	0.88	0.00	106418	117	170.53	135.00	3
Port Angeles-W 14th St	18.83	6.97	0.02	5	0.60	0.35	35820	0.07	8.82	59.96	0.00	137834	0	358.00	35.10	3
Port Townsend-San Juan Ave	13.48	5.37	0.00	0	0.22	0.16	29129	0.15	6.98	159.14	0.00	63268	0	398.13	5.70	3
Pullman-Dexter SE	16.94	5.53	0.01	9	0.35	0.19	38031	0.15	12.91	5.83	0.00	158609	35396	721.64	58.60	2
Puyallup-128th St	22.82	6.68	0.04	37	0.11	0.05	242969	0.28	6.12	57.64	0.00	820219	0	173.84	48.50	3
Ritzville-Alder St	13.76	4.83	0.01	9	0.07	-0.10	7309	-0.06	7.65	0.90	0.00	140614	3261	2197.10	32.20	2
Rosalia-Josephine St	13.17	4.72	0.00	0	0.48	0.15	4594	-0.03	6.25	2.63	0.00	38254	35396	661.91	61.30	2
Seattle-10th & Weller	20.50	10.01	0.02	0	0.00	0.00	313235	0.10	5.73	96.92	0.00	2958856	0	43.28	18.00	0
Seattle-Beacon Hill	15.51	6.16	0.00	2	0.26	0.07	53254	0.02	14.05	121.69	0.00	2773890	0	14.28	54.90	0
Seattle-Duwamish	22.87	9.72	0.04	62	1.63	0.70	67726	0.07	5.13	137.44	0.00	2392587	0	21.26	10.10	2
Seattle-South Park	21.78	9.03	0.03	31	0.32	0.14	160269	0.06	17.10	129.75	0.00	2157831	0	51.04	20.60	3
Shelton-W Franklin	20.63	6.97	0.02	0	-1.19	-0.48	40213	0.19	11.38	55.85	0.00	204694	0	255.33	10.80	3
Spokane-Augusta Ave	23.54	8.71	0.04	27	0.21	0.34	88157	0.06	11.84	72.65	0.00	1094847	0	65.85	42.80	3
Spokane-Monroe St	23.48	7.13	0.04	24	0.08	0.28	132122	0.13	7.72	48.72	0.00	782887	0	214.50	30.60	3
Tacoma-Alexander Ave	22.58	7.84	0.03	37	-0.13	0.03	144034	0.08	10.29	164.24	0.00	2178723	0	68.01	21.20	2
Tacoma- L Street	29.68	7.90	0.06	97	-0.16	0.04	271809	0.03	13.13	90.02	0.00	2189075	0	72.91	8.93	3
Taholah-Quinault Tribe	6.56	3.48	0.00	0	0.00	0.00	3442	0.00	19.09		0.00	5040	0	1292.58	0.00	2
Toppenish-Yakama Tribe	36.99	9.15	0.10	100	1.94	0.69	56262	0.09	32.54	0.02	0.00	236030	0	241.32	69.00	3
Tulalip-Tulalip Tribe	13.40	4.29	0.00	8	1.08	0.39	47302	0.13	4.81	11.28	0.00	0	0	250.42	35.80	2
Twisp-Glover St	24.39	9.10	0.05	98	0.39	0.00	2001	0.01	16.04	0.50	0.00	35482	117	126.42	127.00	3
Vancouver NE 84th Ave	29.84	7.96	0.05	26	0.99	0.39	343007	0.23	9.99	179.40	0.00	1597246	0	197.03	6.15	3
Walla Walla-12th St	18.72	5.88	0.01	0	-0.34	-0.17	51397	0.07	10.69	1.07	0.00	150785	32499	770.46	7.79	3
Wellpinit-Spokane Tribe	14.84	5.40	0.00	79	0.50	0.24	14475	0.12	10.69	0.00	0.00	0	52	2216.71	95.20	1
Wenatchee-Fifth St	32.43	8.79	0.08	51	-1.03	-0.59	66717	0.17	11.91	90.53	0.00	369254	112	117.55	63.40	3
White Swan-Yakama Tribe	22.94	6.12	0.03	7	-0.15	0.17	2611	-0.08	17.42	0.00	0.00	0	0	123.32	88.50	3
Winthrop-Chewuch Rd	18.71	7.10	0.02	0	-0.23	-0.21	2312	0.28	6.97	0.27	0.00	24866	117	263.92	128.00	3
Yacolt-Yacolt Rd	18.79	5.24	0.02	99	1.42	0.70	37266	0.18	5.66	0.10	0.00	9103	0	283.65	52.80	3
Yakima-4th Ave	34.07	8.92	0.08	91	0.98	0.39	111887	0.06	22.50	4.68	0.00	440391	0	146.17	48.30	3

Table 11. $PM_{2.5}$ Decision Matrix Results (scores)

Site	Total Score	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Cheeka Peak	20.20	1.58	2.25	0.06	0.20	0.30	0.19	0.18	0.00	3.81	0.00	8.43	0.00	0.00	3.21	0.00	0
Taholah-Quinault Tribe	27.11	1.77	3.47	0.16	0.00	0.00	0.00	0.08	0.00	5.87	0.00	7.44	0.02	0.00	4.30	0.00	4
Neah Bay 2-Makah Tribe	29.27	2.30	3.67	0.06	0.00	1.21	1.47	0.03	0.00	4.65	0.00	8.43	0.01	0.00	0.87	6.57	0
Ritzville-Alder St	30.57	3.72	4.82	0.61	0.90	0.19	0.46	0.16	0.00	2.35	0.04	2.23	0.48	0.92	7.31	2.39	4
LaCrosse-Hill St	35.02	3.69	4.31	0.34	0.00	1.56	0.87	0.04	0.00	1.55	0.00	2.53	0.04	10.00	4.09	2.01	4
Rosalia-Josephine St	35.79	3.56	4.71	0.06	0.00	1.24	0.68	0.10	0.00	1.92	0.12	2.53	0.13	10.00	2.20	4.54	4
Mt Vernon-S Second St	35.81	2.80	4.42	0.00	0.00	0.01	0.45	2.09	4.84	3.25	1.84	7.51	2.23	0.00	2.00	0.38	4
Tulalip-Tulalip Tribe	36.63	3.62	4.28	0.24	0.80	2.78	1.72	1.05	3.80	1.48	0.52	8.85	0.00	0.00	0.83	2.65	4
Oakville-Chehalis Tribe	36.75	4.11	4.67	0.18	0.00	3.49	2.65	0.52	5.88	2.98	0.21	7.44	0.16	0.00	1.44	1.04	2
North Bend-North Bend Way	36.86	4.05	5.41	0.65	0.80	0.58	0.71	1.36	7.59	0.91	0.00	5.21	1.29	0.00	2.06	0.24	6
Dayton-W Main St	38.90	3.98	5.34	0.44	0.00	0.32	0.27	0.17	0.00	2.73	0.00	7.95	0.10	7.48	4.58	1.55	4
Anacortes 202 Avenue	39.44	3.72	6.74	0.16	0.00	3.68	5.00	0.59	2.99	1.39	4.55	7.51	0.37	0.00	1.31	1.43	0
Mesa-Pepiot Way	41.15	4.83	5.84	1.12	0.20	0.15	0.04	0.54	5.13	8.48	0.04	2.04	0.35	1.12	4.76	2.50	4
White Swan-Yakama Tribe	41.32	6.20	6.11	2.78	0.70	0.38	0.76	0.06	0.00	5.35	0.00	6.01	0.00	0.00	0.41	6.56	6
Chehalis-Market Blvd	41.51	4.41	6.03	0.71	0.00	1.09	1.19	1.56	4.13	3.87	3.87	8.38	2.00	0.00	2.19	0.08	2
Seattle-Beacon Hill	42.26	4.19	6.15	0.38	0.20	0.66	0.33	1.18	0.52	4.32	5.63	5.21	9.37	0.00	0.05	4.07	0
Aberdeen-Division St	42.35	3.51	4.61	0.00	0.00	2.45	1.44	0.69	0.98	4.55	10.00	7.44	0.89	0.00	0.46	3.31	2
Port Townsend-San Juan Ave	43.03	3.64	5.36	0.00	0.00	0.57	0.70	0.65	4.64	2.14	7.37	10.00	0.21	0.00	1.33	0.42	6
Port Angeles-W 14th St	44.16	5.09	6.96	1.54	0.50	1.54	1.55	0.79	2.03	2.71	2.78	8.43	0.47	0.00	1.19	2.60	6
Longview-30th Ave	45.72	4.53	5.51	0.88	0.00	1.53	1.77	2.05	2.34	3.86	6.15	7.30	1.80	0.00	1.36	0.64	6
Bremerton-Spruce Ave	45.87	3.28	4.74	0.21	0.40	2.66	1.30	5.91	2.74	1.84	0.83	9.14	1.92	0.00	1.73	3.17	6
Walla Walla-12th St	46.00	5.06	5.87	1.27	0.00	0.86	0.77	1.14	2.24	3.29	0.05	6.62	0.51	9.18	2.56	0.58	6
Pullman-Dexter SE	47.21	4.58	5.52	1.14	0.90	0.90	0.85	0.84	4.43	3.97	0.27	2.53	0.54	10.00	2.40	4.34	4
Bellevue-Bellevue Way	49.30	3.49	4.76	0.06	0.00	1.27	1.19	9.73	5.32	1.21	2.51	5.21	9.99	0.00	0.85	3.71	0
Shelton-W Franklin	49.38	5.58	6.96	1.98	0.00	3.07	2.12	0.89	5.77	3.50	2.58	8.58	0.69	0.00	0.85	0.80	6
Winthrop-Chewuch Rd	49.60	5.06	7.09	1.62	0.00	0.60	0.92	0.05	8.31	2.14	0.01	7.32	0.08	0.03	0.88	9.48	6
Bellingham-Yew St	50.03	4.18	5.97	0.17	0.00	2.65	1.60	2.79	5.83	2.76	4.78	9.95	1.93	0.00	0.99	4.44	2
Clarkston-13th St	50.21	6.96	8.12	3.77	0.70	1.88	1.42	0.46	1.47	2.62	5.82	3.00	0.25	0.19	0.42	7.13	6
Seattle-10th & Weller	50.79	5.54	10.00	2.24	0.00	0.00	0.00	6.95	3.13	1.76	4.49	5.21	10.00	0.00	0.14	1.33	0

Table 11. $PM_{2.5}$ Decision Matrix Results (scores)

Site	Total Score	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Spokane-Monroe St	50.94	6.35	7.12	3.39	2.40	0.20	1.22	2.93	4.01	2.37	2.25	7.07	2.65	0.00	0.71	2.27	6
Kennewick-Metaline	51.43	5.09	6.20	1.31	0.00	0.20	0.12	5.19	10.00	3.70	0.27	2.21	2.93	0.00	5.69	2.52	6
Wellpinit-Spokane Tribe	51.81	4.01	5.40	0.33	7.90	1.29	1.05	0.32	3.64	3.29	0.00	8.14	0.00	0.01	7.38	7.05	2
Colville-Oak St S	51.96	6.83	9.05	5.90	0.50	0.51	0.36	0.36	0.09	3.23	1.06	8.14	0.30	0.01	1.68	7.93	6
Lake Forest Park-Town Center	52.13	6.33	7.37	3.76	2.10	0.69	0.30	7.82	3.12	1.50	1.11	5.21	7.08	0.00	0.39	1.36	4
Moses Lake-Balsam St	52.75	5.11	6.28	1.64	0.00	1.32	0.80	1.59	4.74	5.63	0.13	2.49	0.90	1.83	10.00	4.27	6
Leavenworth-Evans St	53.71	7.05	7.86	4.41	0.80	5.00	2.97	0.21	0.90	2.47	0.00	7.03	0.31	0.03	0.88	7.78	6
Spokane-Augusta Ave	54.07	6.36	8.70	3.41	2.70	0.55	1.52	1.96	1.71	3.64	3.36	7.07	3.70	0.00	0.22	3.17	6
Yacolt-Yacolt Rd	54.75	5.08	5.23	1.83	9.90	3.67	3.12	0.83	5.53	1.74	0.00	6.93	0.03	0.00	0.94	3.91	6
Tacoma-Alexander Ave	55.93	6.10	7.83	3.28	3.70	0.35	0.15	3.20	2.44	3.16	7.60	4.96	7.36	0.00	0.23	1.57	4
Lynnwood-212	56.16	5.79	6.23	2.33	0.10	1.16	0.87	6.66	3.95	2.70	0.49	8.85	7.61	0.00	0.40	3.02	6
Puyallup-128th St	57.00	6.17	6.67	3.65	3.70	0.29	0.22	5.39	8.45	1.88	2.67	4.96	2.77	0.00	0.58	3.59	6
Seattle-South Park	58.86	5.89	9.01	2.68	3.10	0.82	0.62	3.56	1.72	5.26	6.01	5.21	7.29	0.00	0.17	1.53	6
Marysville-7th Ave	59.37	6.90	7.68	4.34	6.10	1.16	1.31	4.04	4.91	2.78	0.64	8.85	4.16	0.00	0.42	0.07	6
Twisp-Glover St	60.36	6.59	9.08	5.26	9.80	1.01	0.02	0.04	0.29	4.93	0.02	7.32	0.12	0.03	0.42	9.41	6
Ellensburg-Ruby St	62.10	8.00	7.29	5.69	7.70	0.21	0.17	0.66	6.95	3.84	0.09	7.53	0.76	0.05	0.80	6.36	6
Seattle-Duwamish	62.52	6.18	9.71	3.53	6.20	4.19	3.10	1.50	2.05	1.58	6.36	5.21	8.09	0.00	0.07	0.75	4
Darrington-Fir St	62.73	7.63	6.80	5.77	8.90	1.14	1.03	0.05	4.22	2.48	0.33	8.85	0.08	0.00	0.41	9.04	6
Omak-Colville Tribe	64.38	8.21	8.60	6.58	9.20	1.83	1.54	0.22	0.62	3.25	0.04	7.32	0.36	0.03	0.57	10.00	6
Lacey-College St	64.39	6.81	6.52	3.85	8.50	3.38	3.07	4.44	5.70	2.15	0.09	7.79	3.33	0.00	1.14	1.60	6
Tacoma- L Street	66.58	8.02	7.89	5.85	9.70	0.42	0.18	6.03	1.03	4.04	4.17	4.96	7.40	0.00	0.24	0.66	6
Yakima-4th Ave	68.76	9.21	8.91	8.20	9.10	2.52	1.73	2.48	1.91	6.91	0.22	6.01	1.49	0.00	0.49	3.58	6
Kent-Central & James	69.66	6.12	6.99	3.16	4.70	0.37	2.99	10.00	4.64	3.22	3.69	5.21	9.52	0.00	0.75	2.30	6
Wenatchee-Fifth St	69.70	8.77	8.78	7.89	5.10	2.67	2.64	1.48	5.13	3.66	4.19	7.03	1.25	0.03	0.39	4.70	6
Vancouver NE 84th Ave	73.06	8.07	7.95	4.81	2.60	2.56	1.74	7.61	6.91	3.07	8.30	6.93	5.40	0.00	0.66	0.46	6
Toppenish-Yakama Tribe	79.78	10.00	9.14	10.00	10.00	4.99	3.08	1.25	2.60	10.00	0.00	6.01	0.80	0.00	0.80	5.11	6

$PM_{2.5}$: 24-Hour Design Values

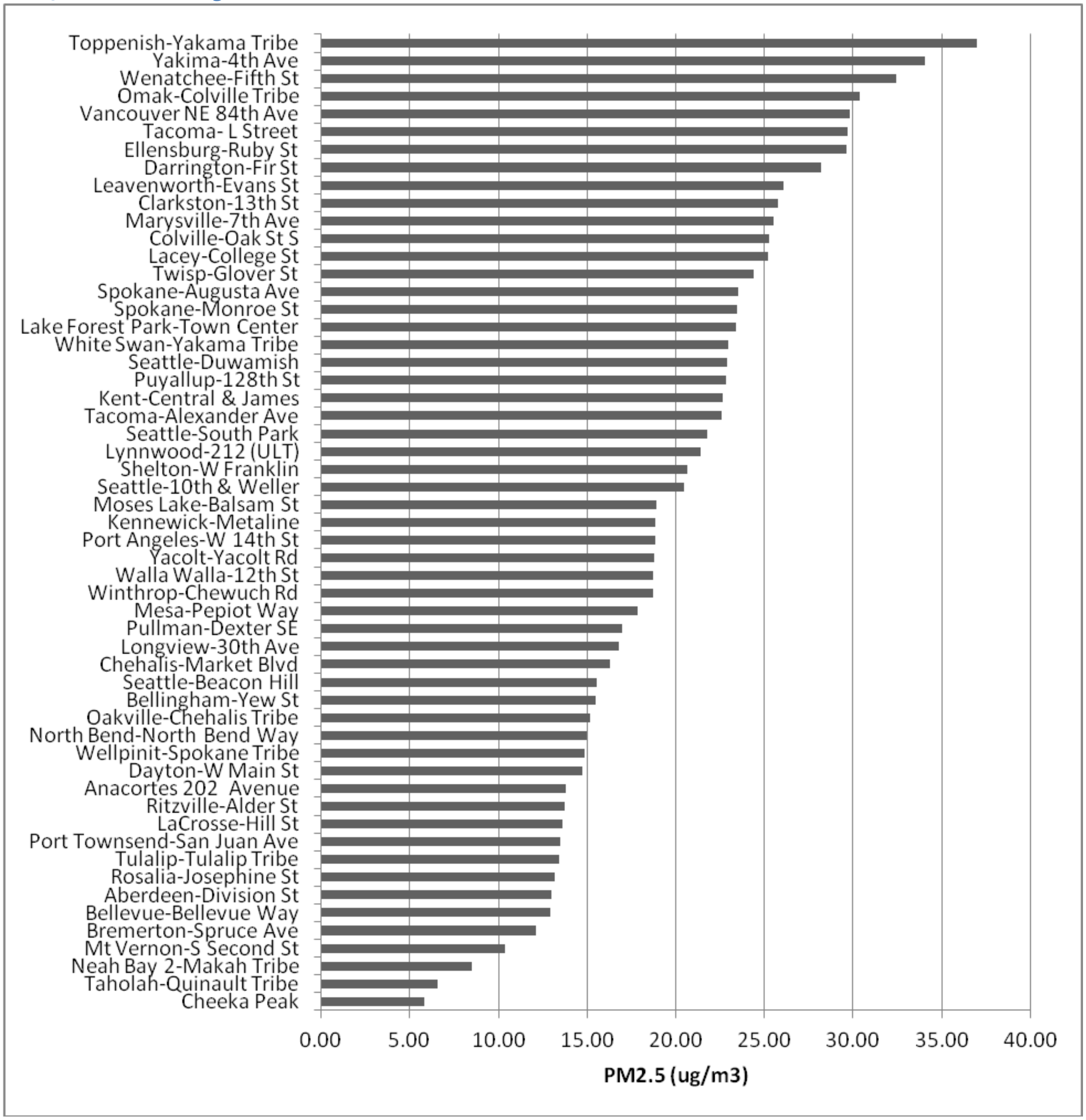


Figure 25. $PM_{2.5}$ decision matrix: 24-hour design values

$PM_{2.5}$: Annual Design Values

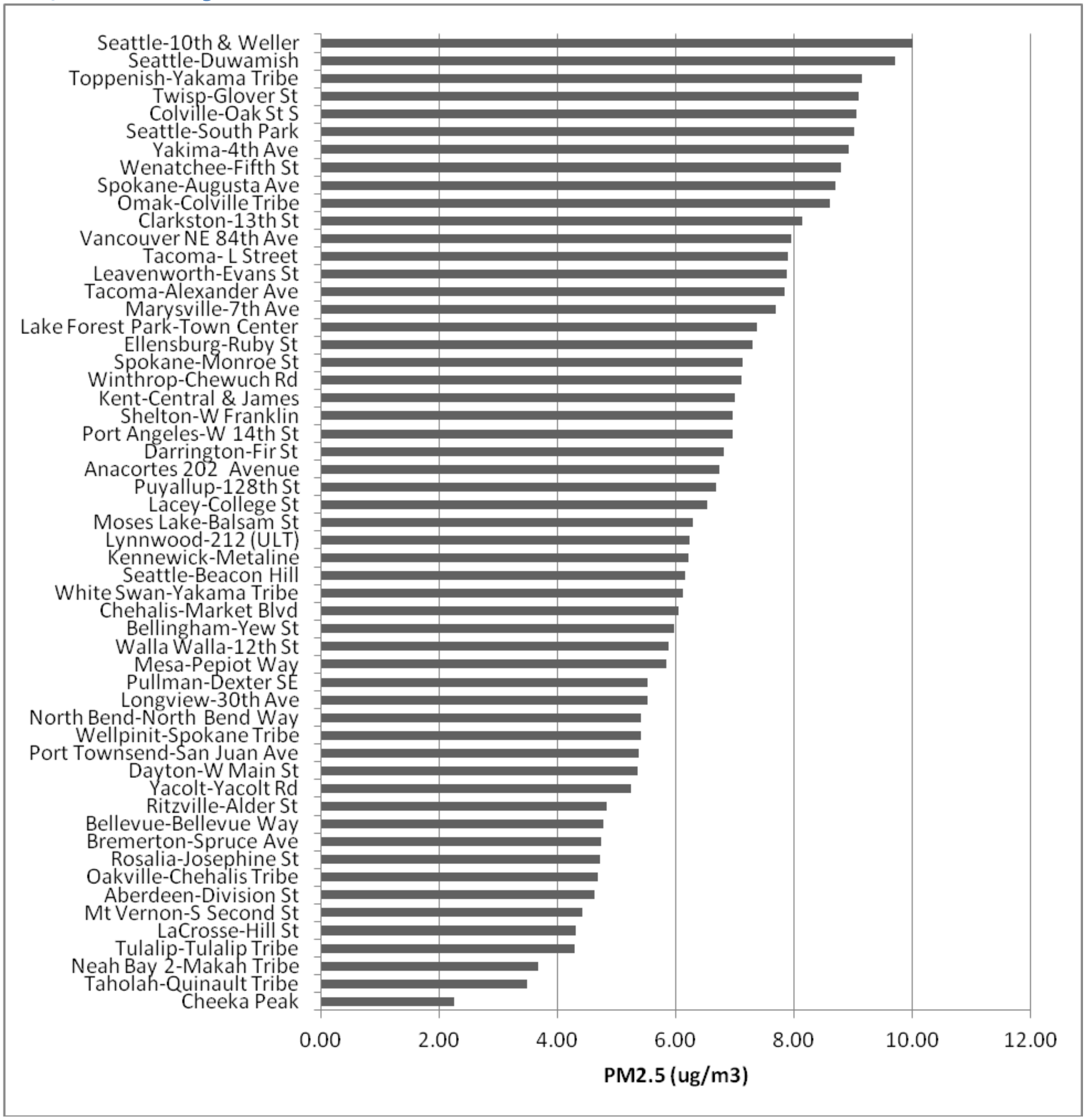


Figure 26. $PM_{2.5}$ decision matrix: annual design values

$PM_{2.5}$: Days over 20 µg/m^3

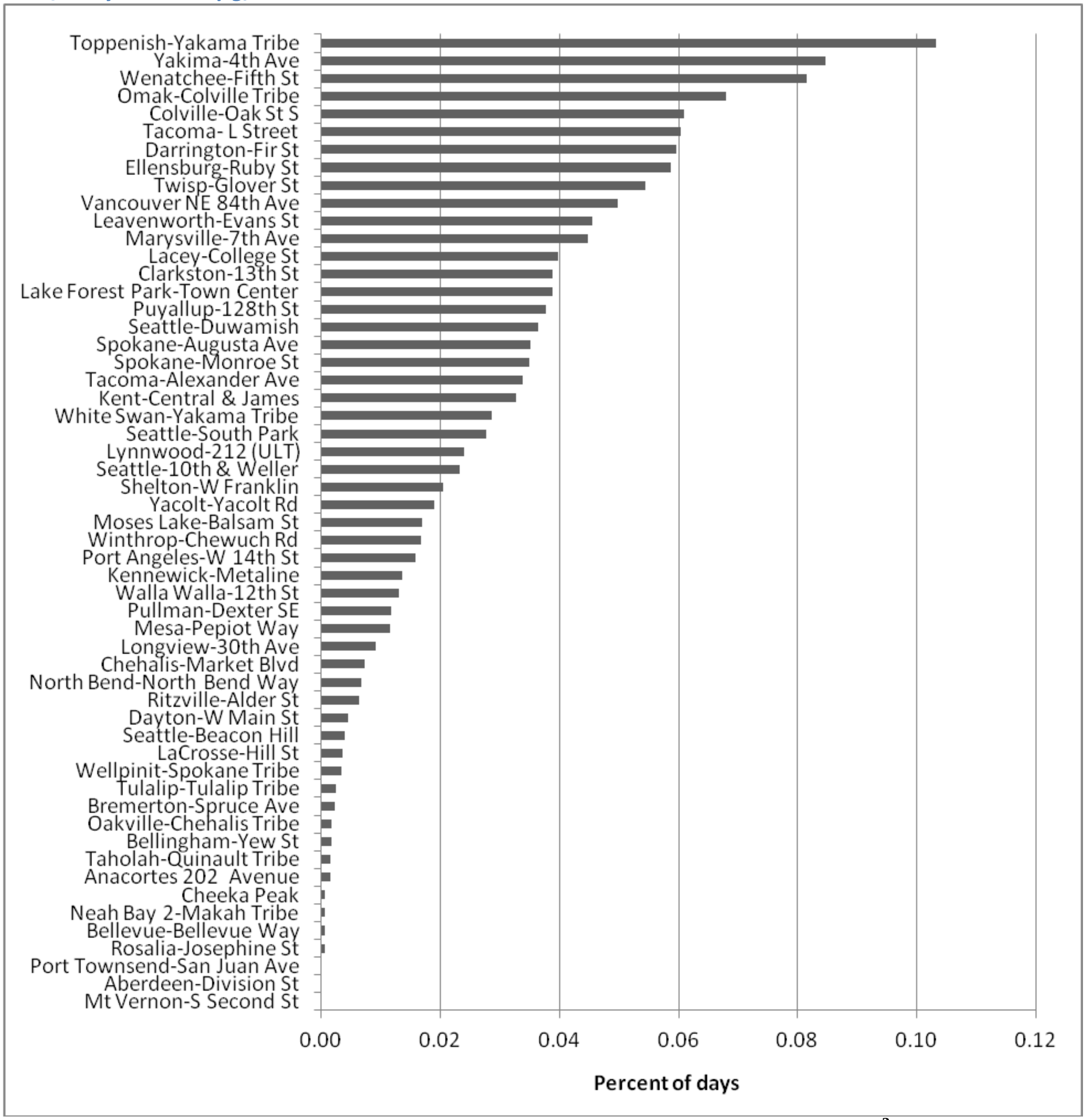


Figure 27. $PM_{2.5}$ decision matrix: percent of days over 20 µg/m^3

$PM_{2.5}$: Probability of a Single Day over 35 µg/m³

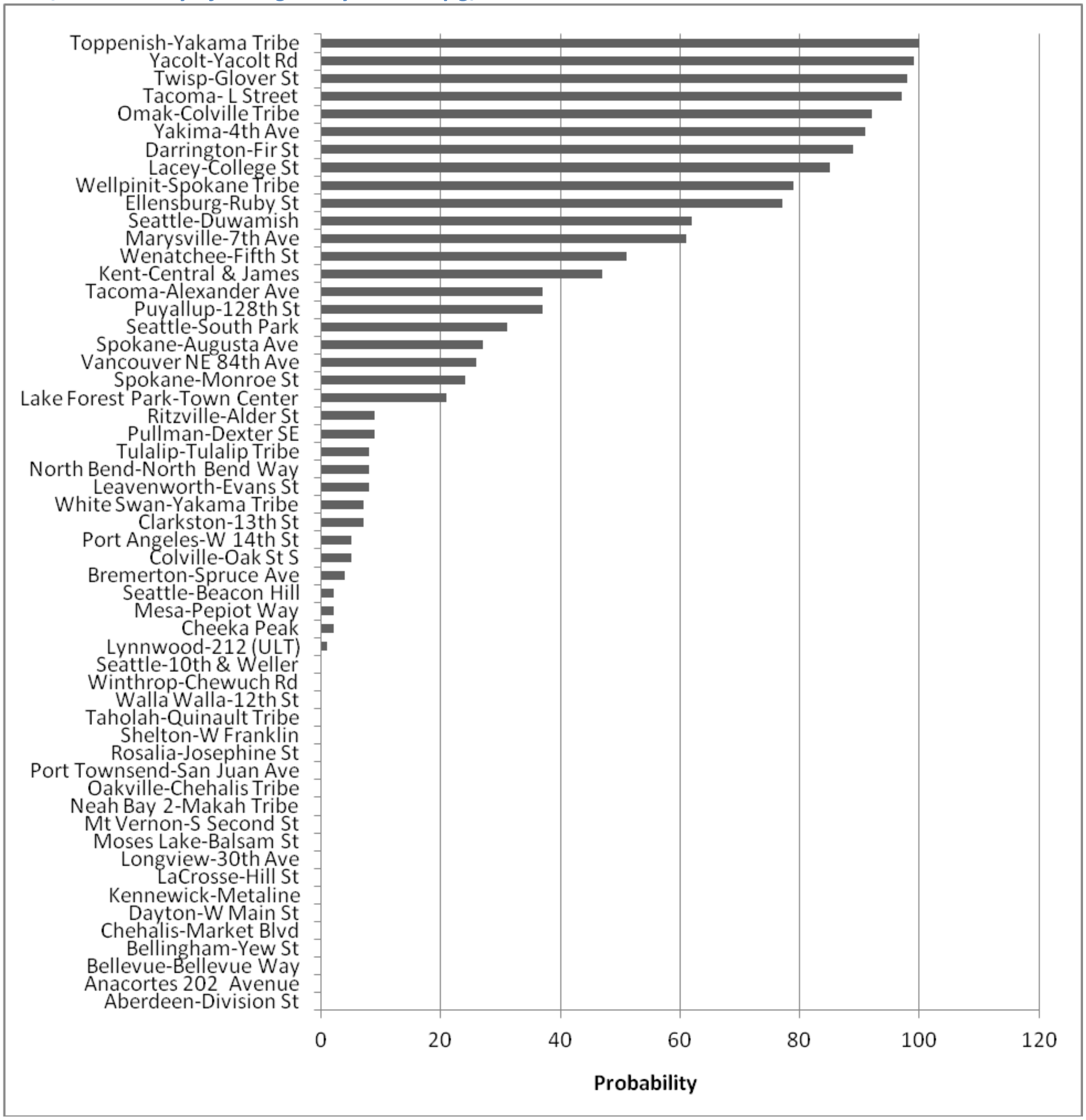


Figure 28. Probability of a single day over 35 ug/m3

$PM_{2.5}$: Trend in 98th Percentile and Annual Mean

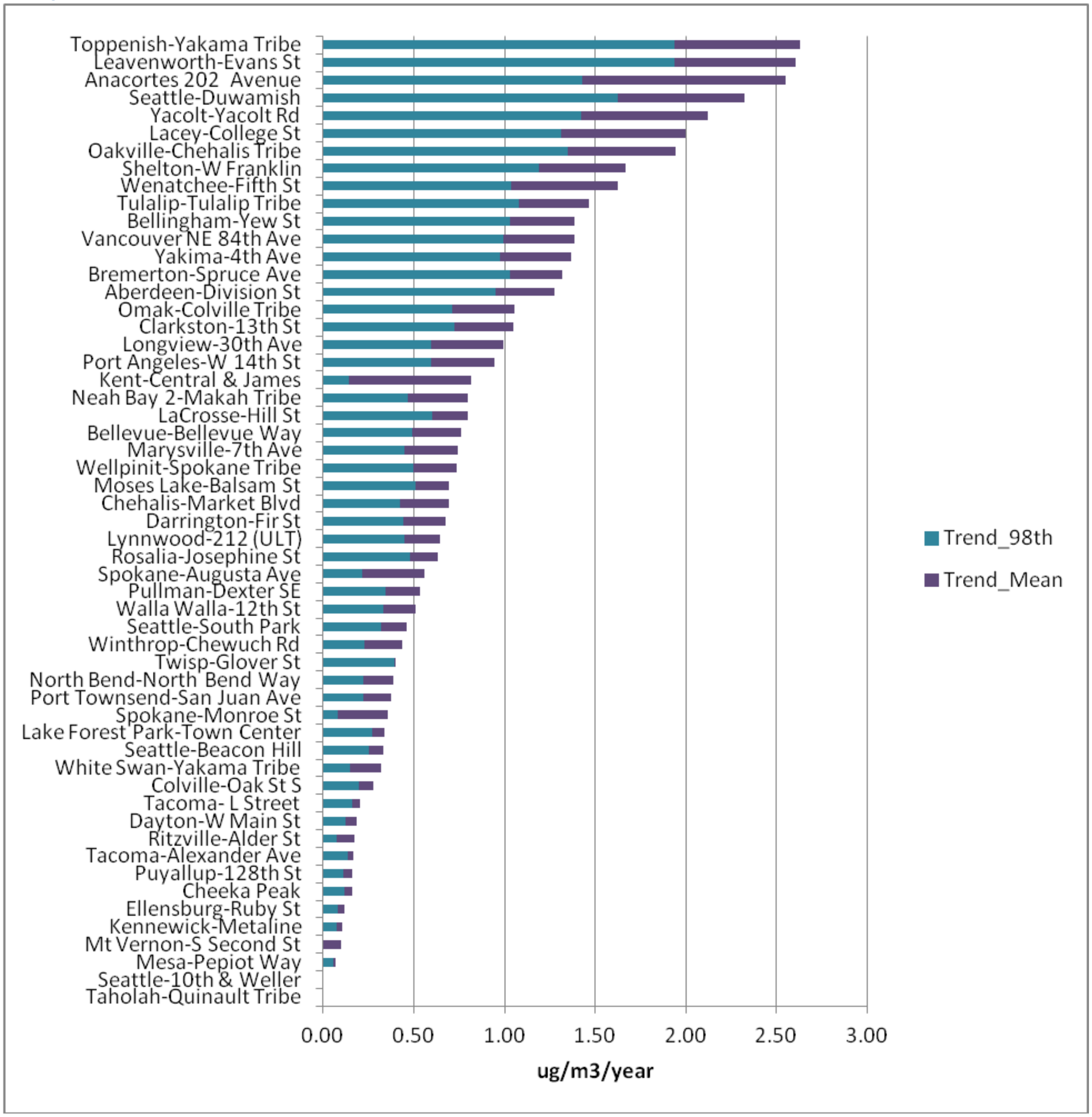


Figure 29. $PM_{2.5}$ decision matrix: absolute value trend in 98th percentile/annual mean

$PM_{2.5}$: Population Served

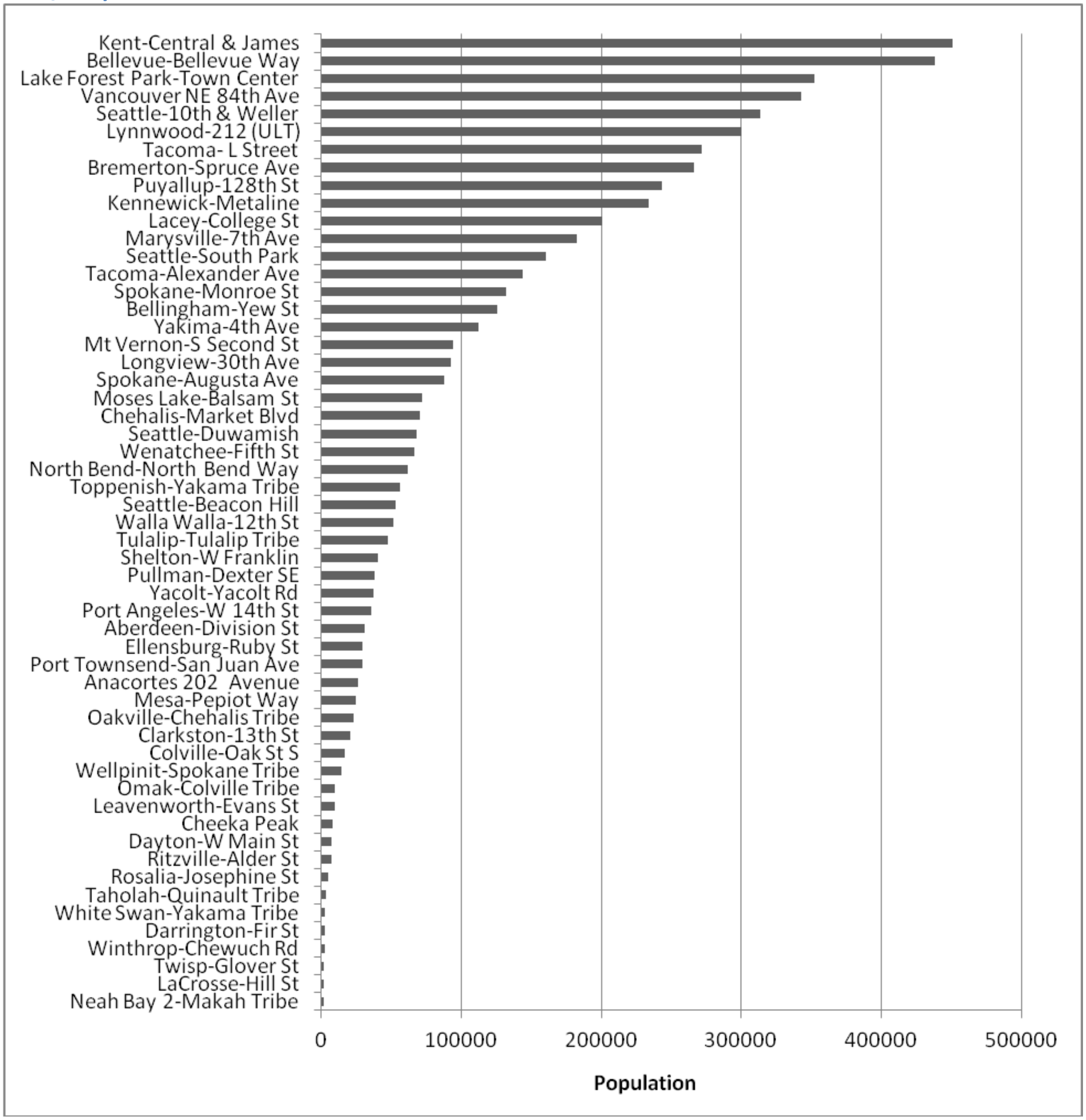


Figure 30. $PM_{2.5}$ decision matrix criteria: population served

$PM_{2.5}$: Population Growth Rate

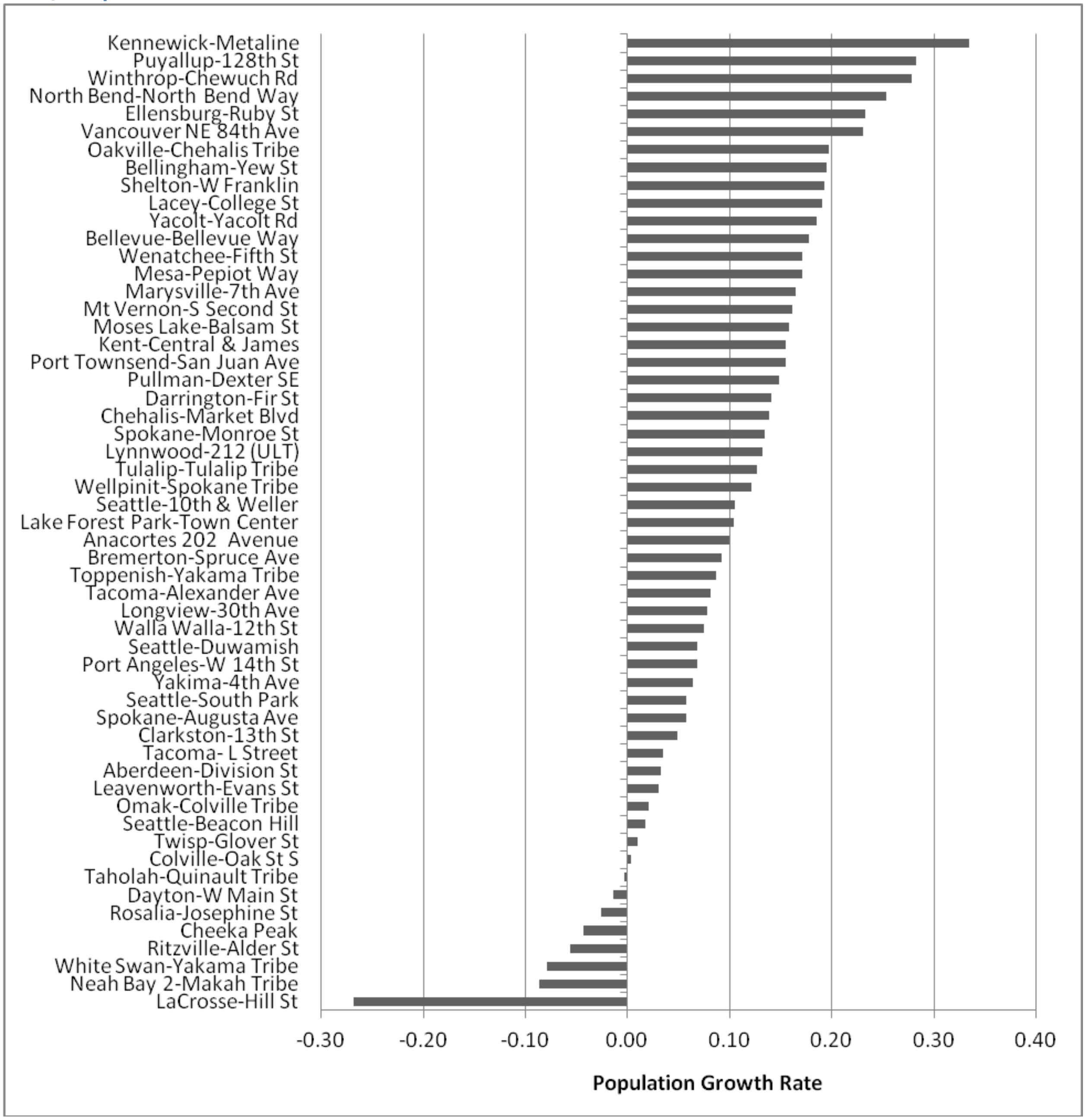


Figure 31. $PM_{2.5}$ decision matrix: population growth rate

PM$_{2.5}$: Environmental Justice Index

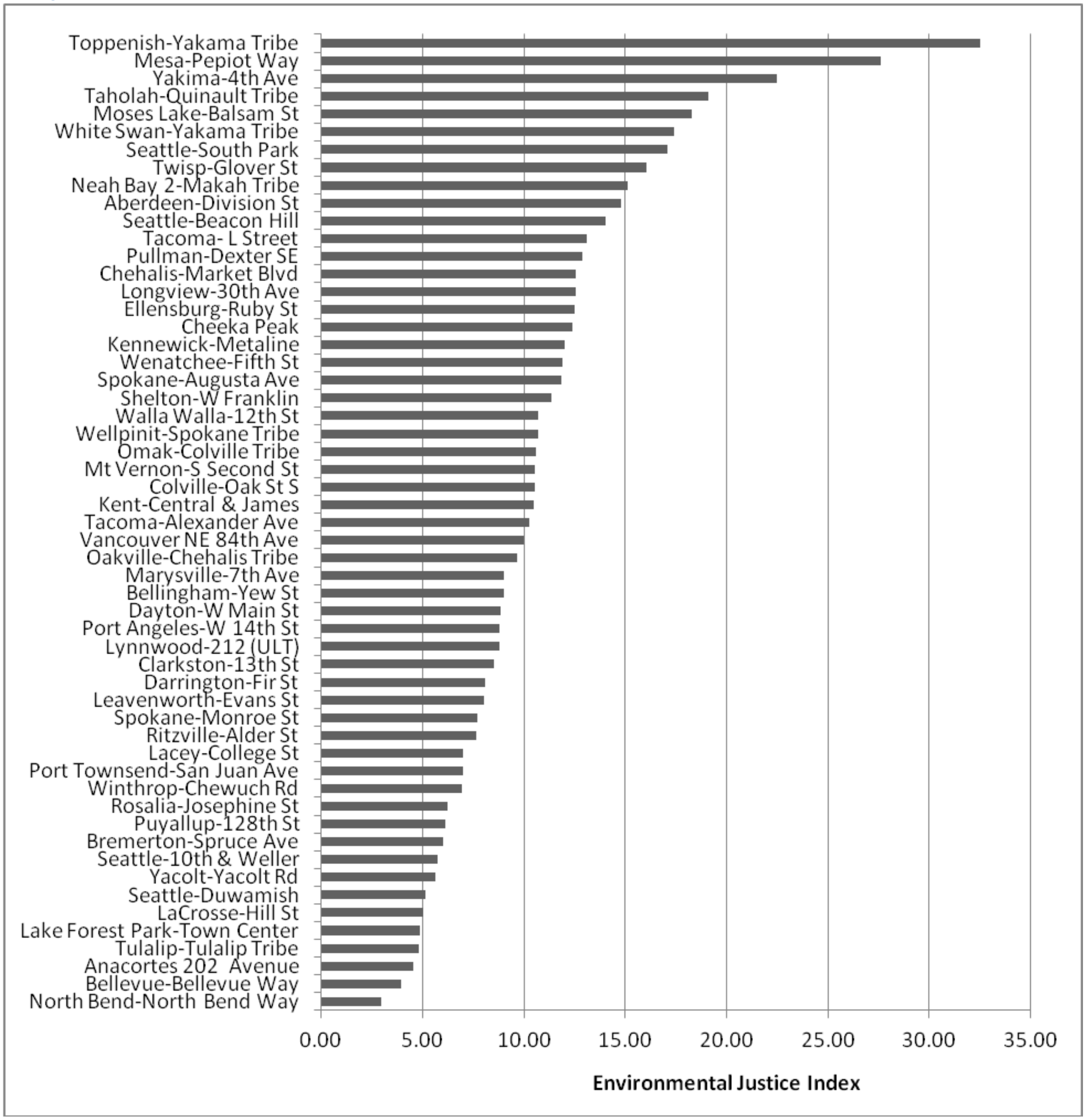


Figure 32. PM$_{2.5}$ decision matrix: environmental justice index

$PM_{2.5}$: Point Source Emissions

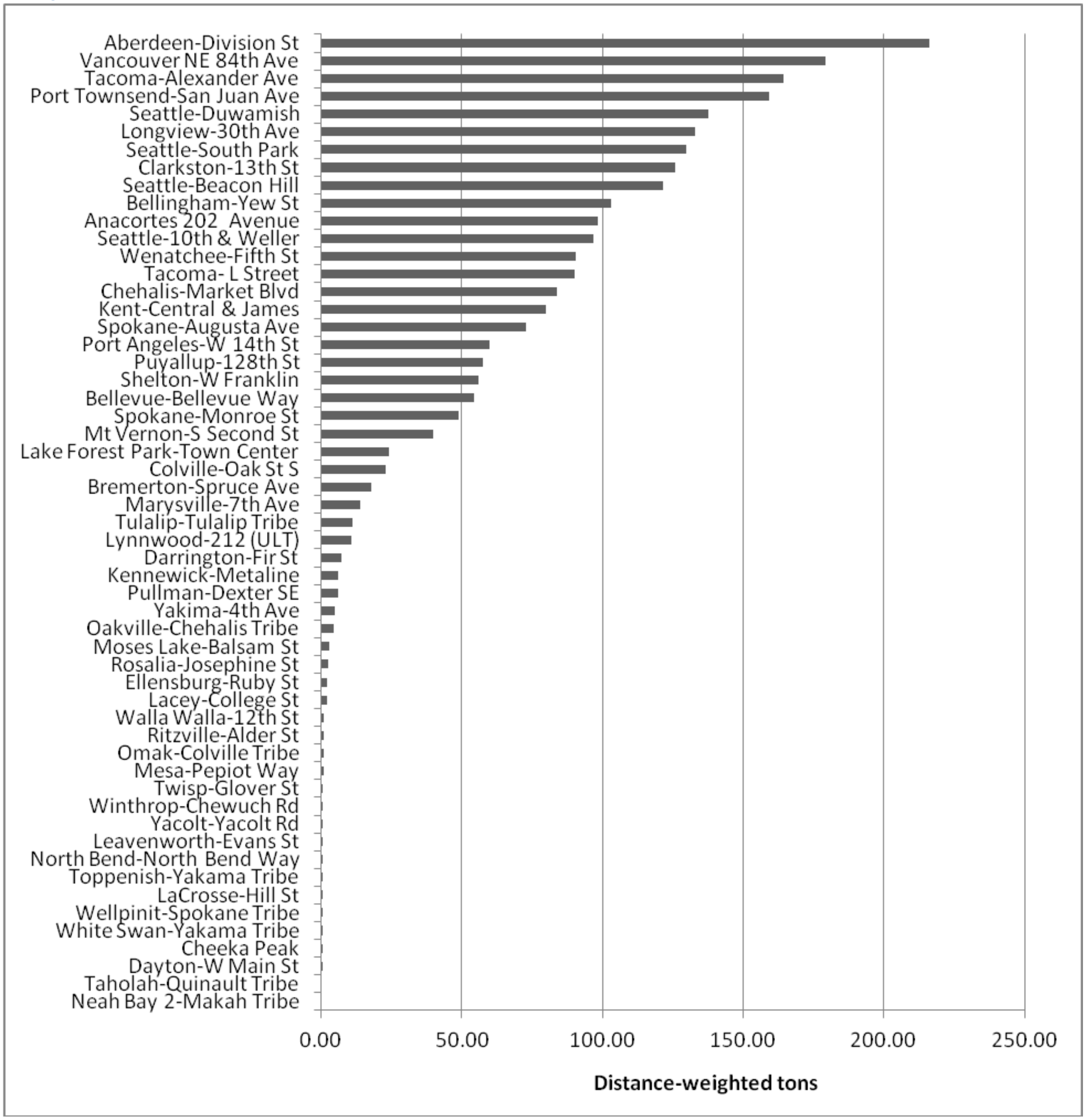


Figure 33. $PM_{2.5}$ decision matrix: point source emissions

$PM_{2.5}$: Smoke Impacts

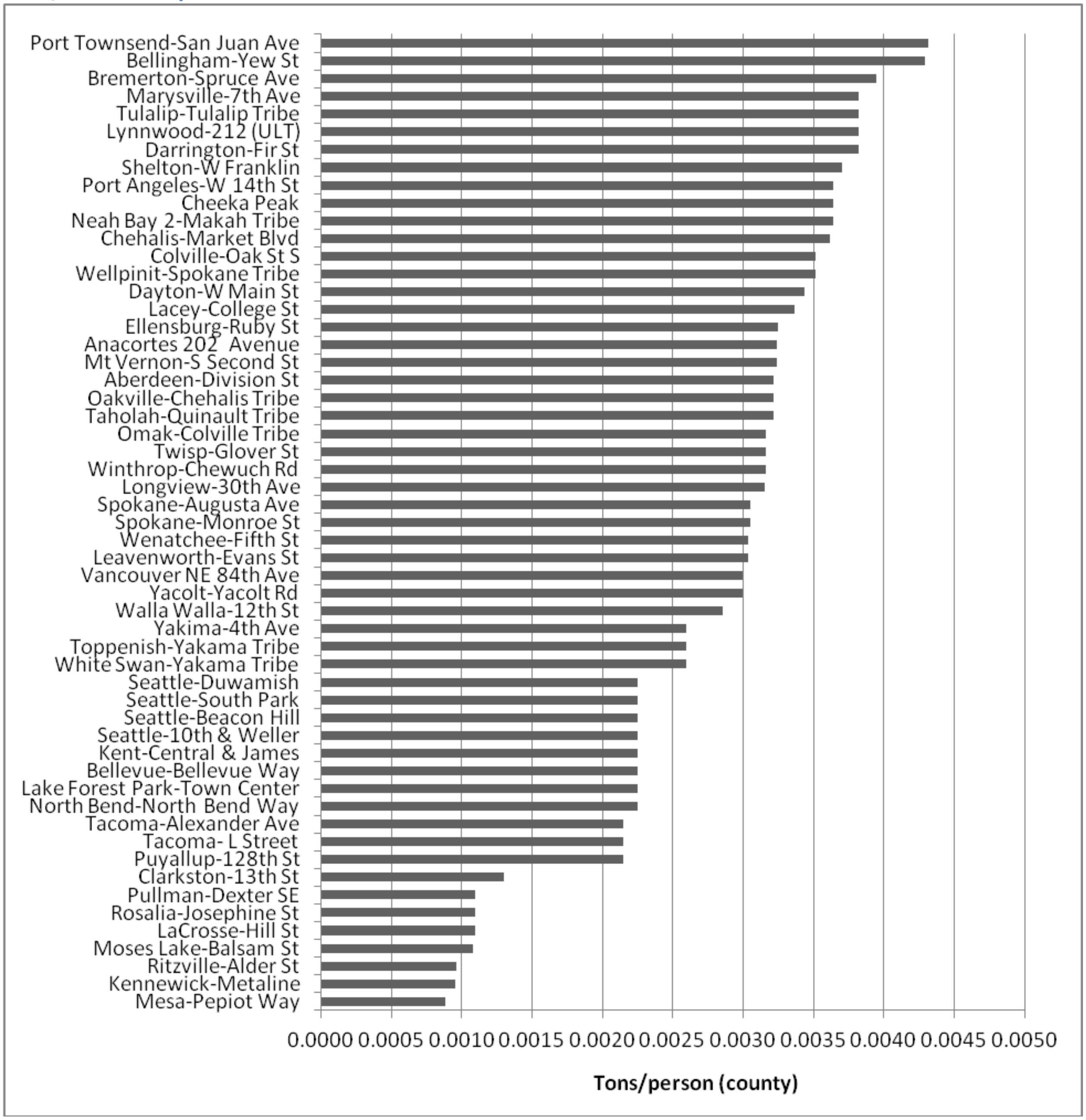


Figure 34. $PM_{2.5}$ decision matrix: smoke impacts

$PM_{2.5}$: Traffic Density

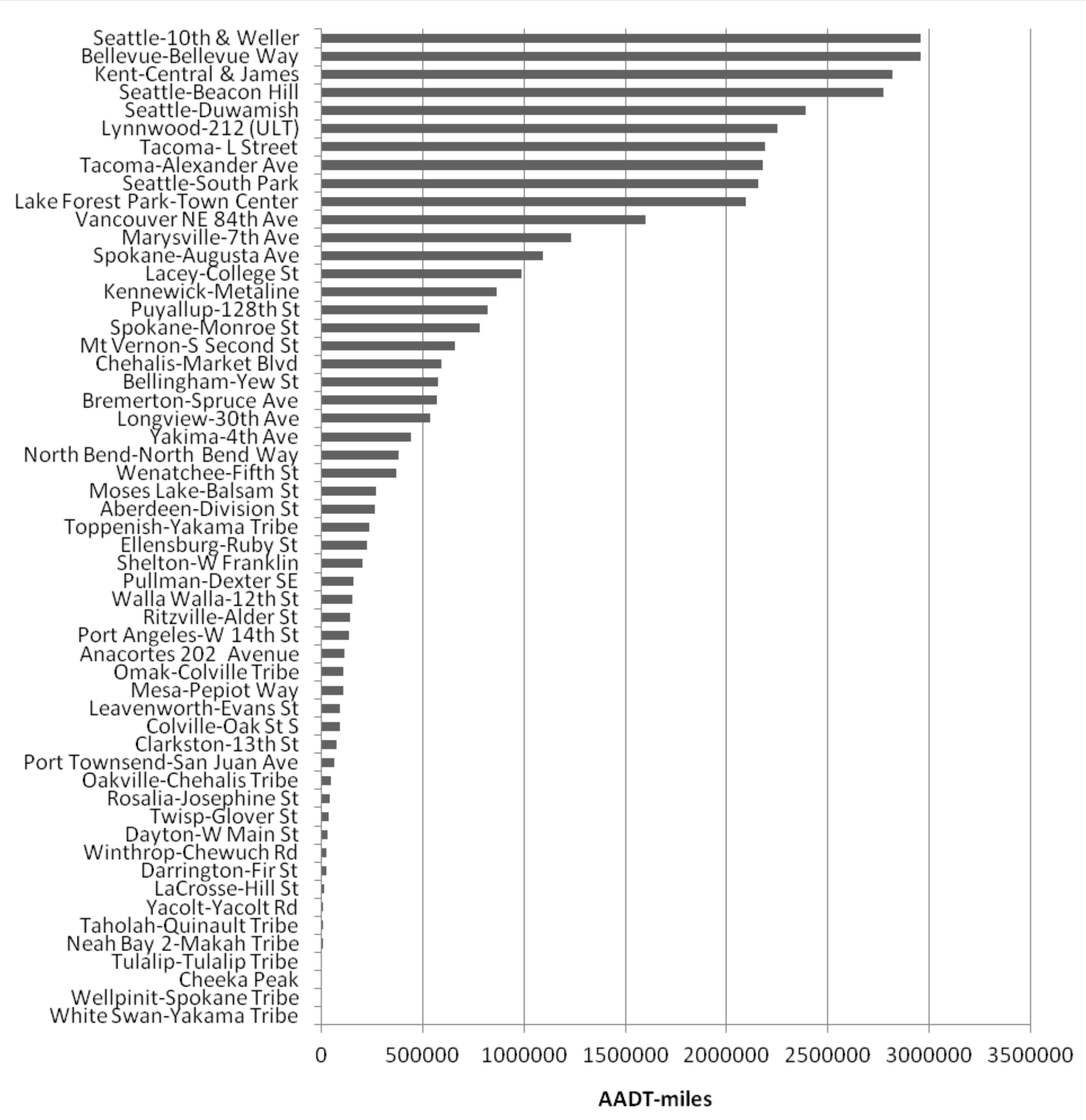


Figure 35. $PM_{2.5}$ decision matrix: traffic density

$PM_{2.5}$: Agricultural/Non-Residential Outdoor Burning

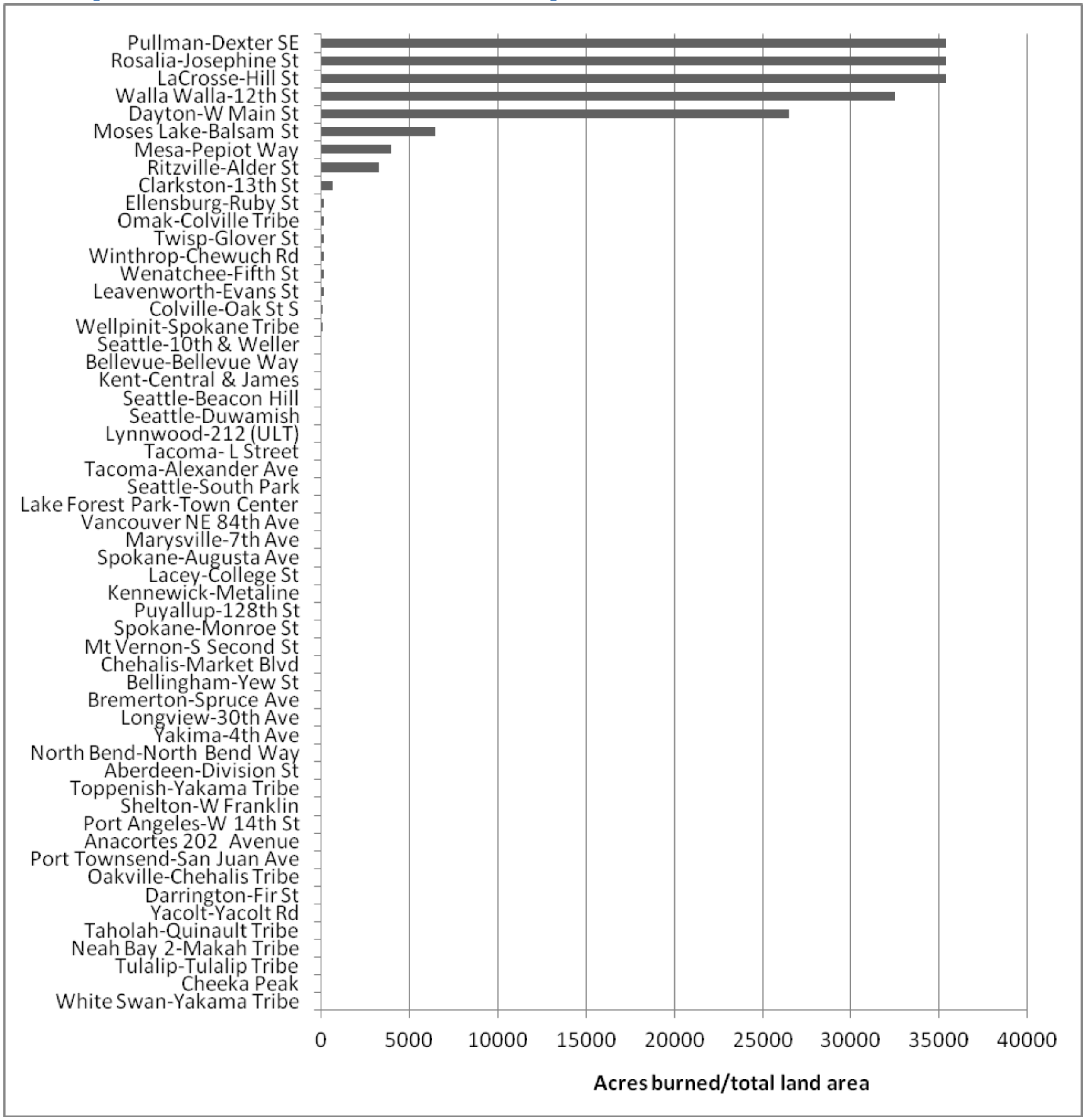


Figure 36. $PM_{2.5}$ decision matrix: acres burned

$PM_{2.5}$: Geographic Area Represented

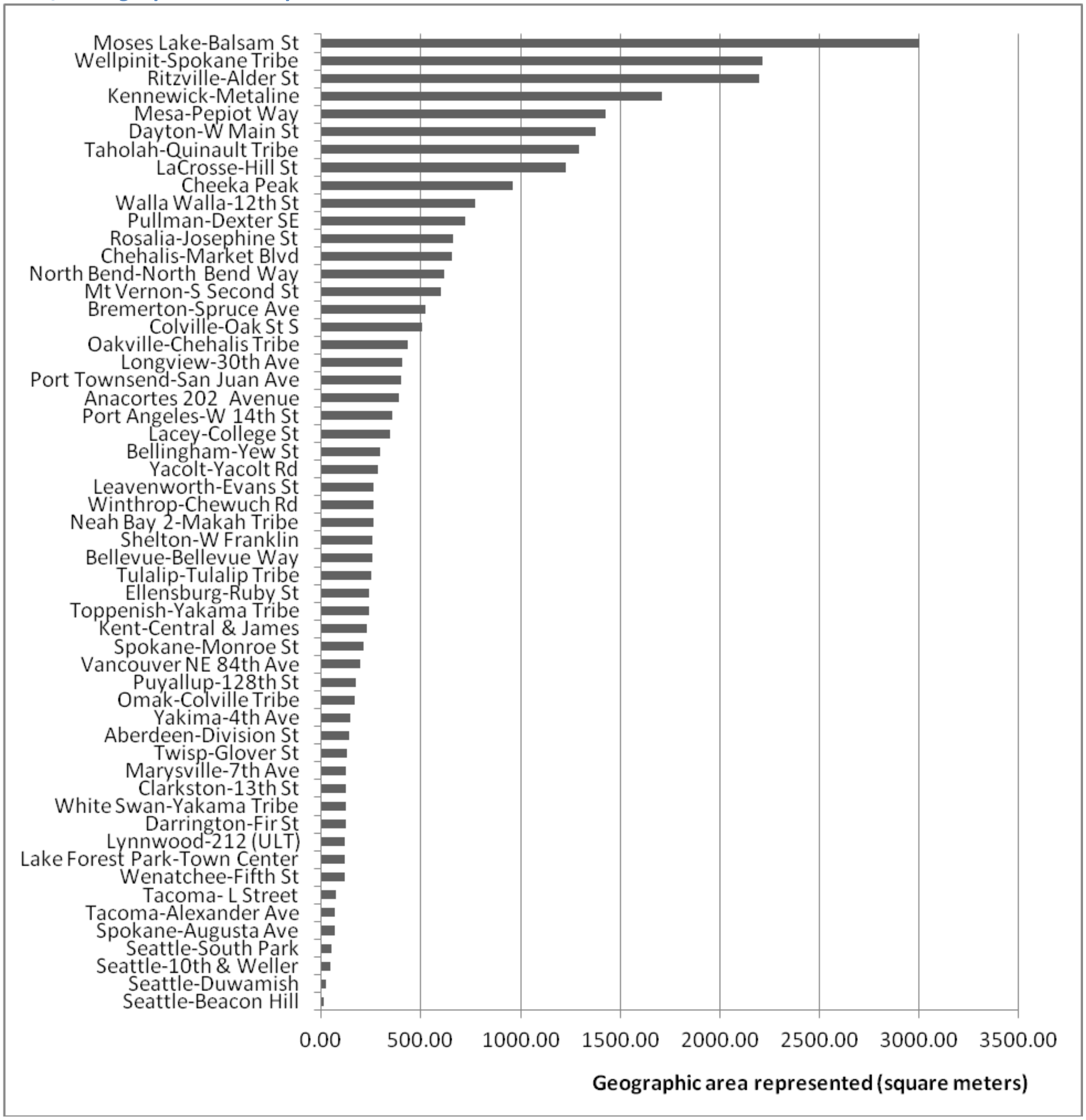


Figure 37. Geographic area represented

$PM_{2.5}$: AIRPACT Model/Monitor Error

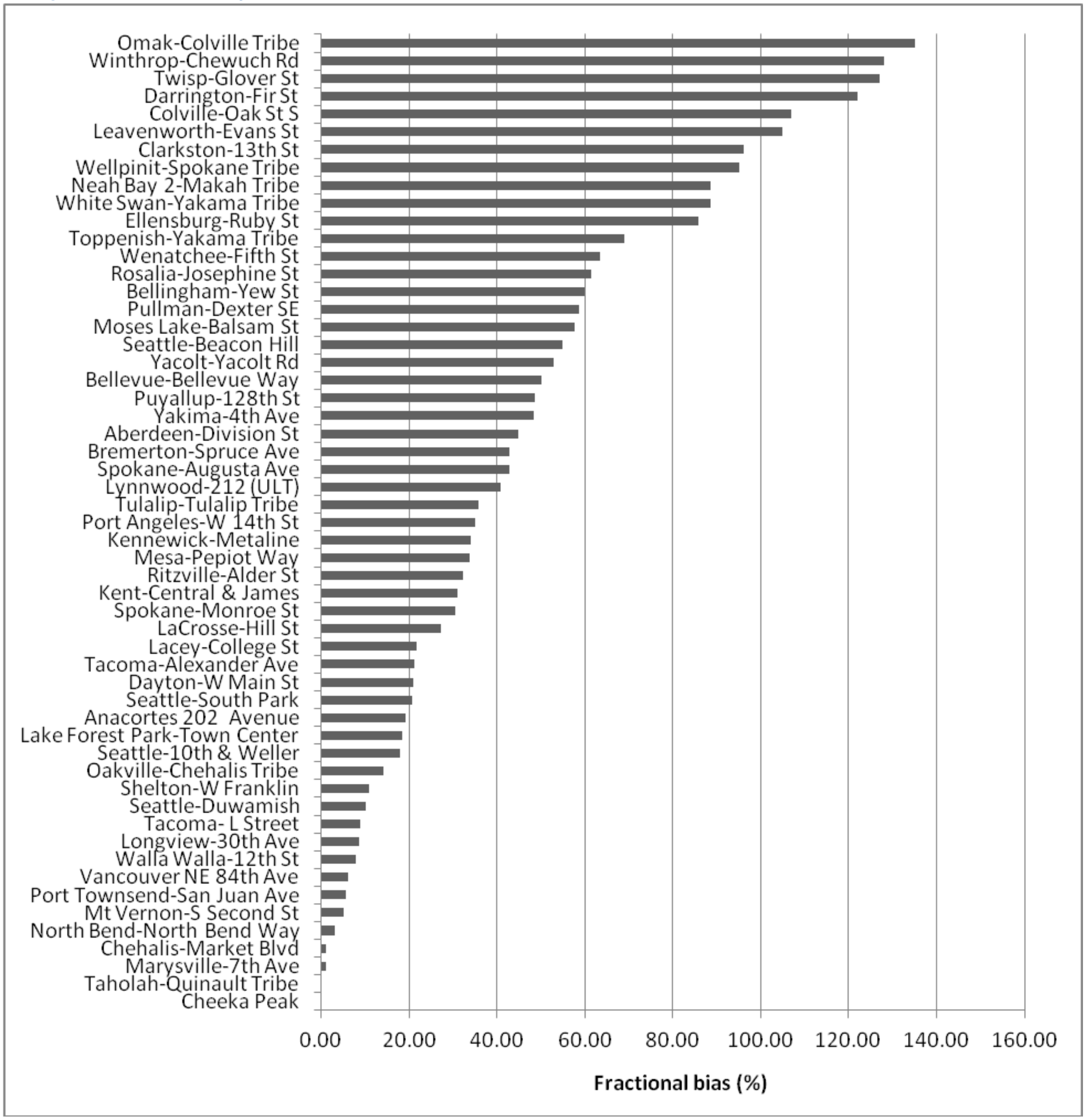


Figure 38. AIRPACT model/monitor error

Appendix B. Ozone Decision Matrix Results

Table 12. Ozone Decision Matrix Results (raw data)

Site Name	DV	75th %ile	Days Over 65	Probability of a Day >70	98th %ile trend	75th %ile trend	Pop. Served	Pop. Growth	EJ	AIRPACT/ Monitor Error
Cheeka Peak	0.044	0.044	0.0000	39	2.89	1.00	4526991	0.06	10.25	21
Cheney-Turnbull	0.052	0.047	0.0000	1	-0.33	0.00	72715	0.02	18.63	2
Custer-Loomis	0.060	0.056	0.0041	9	0.04	0.29	688279	0.03	17.94	0
Spokane-Greenbluff	0.047	0.042	0.0014	2	-0.32	0.19	208351	0.04	17.40	26
Spokane-Augusta Ave.	0.067	0.057	0.0241	87	0.72	0.92	4526991	0.06	10.25	25
Seattle-Beacon Hill	0.054	0.044	0.0028	6	-0.02	0.42	4526991	0.06	10.25	29
Yelm-Northern Pacific	0.068	0.059	0.0320	72	0.00	0.00	274295	0.08	29.05	5
Issaquah-Lake Sammamish	0.057	0.055	0.0014	0	1.22	0.88	4526991	0.06	10.25	12
Mt. Rainier-Jackson	0.058	0.047	0.0079	34	0.15	1.04	4526991	0.06	10.25	29
Vancouver-Blairmont	0.043	0.041	0.0000	0	0.50	0.17	4526991	0.06	10.25	31
Anacortes-202 Ave.	0.060	0.057	0.0070	11	0.75	0.71	688279	0.03	17.94	7
North Bend	0.061	0.056	0.0040	0	0.71	0.89	688279	0.03	17.94	4
Kennewick	0.057	0.047	0.0027	0	-0.97	0.65	3060078	0.05	21.79	24
Enumclaw-Mud Mountain	0.055	0.046	0.0027	12	-0.18	0.06	4526991	0.06	10.25	22

Table 13. Ozone Decision Matrix Results (scores)

Site Name	Total Score	DV	75th %ile	Days Over 65	Probability of a Day >70	98th %ile trend	75th %ile trend	Pop. Served	Pop. Growth	EJ	AIRPACT/ Monitor Error
Cheeka Peak	25.70	7.68	8.01	0.00	0.11	0.58	0.00	0.16	2.22	6.41	0.52
Cheney-Turnbull	34.01	8.95	9.49	1.29	1.03	0.06	1.41	1.52	4.00	6.17	0.08
Custer-Loomis	35.28	6.93	7.03	0.44	0.23	0.55	0.93	0.46	4.33	5.99	8.38
Spokane-Greenbluff	38.14	9.05	9.49	1.26	0.00	1.23	4.28	1.52	4.00	6.17	1.15
Spokane-Augusta Ave	40.47	8.89	9.58	2.18	1.26	1.30	3.39	1.52	4.00	6.17	2.18
Seattle-Beacon Hill	45.56	6.37	6.86	0.00	0.00	0.86	0.81	10.00	7.13	3.53	10.00
Yelm-Northern Pacific	46.39	8.15	7.80	0.83	1.38	0.31	0.28	10.00	7.13	3.53	6.98
Issaquah-Lake Sammamish	49.01	8.00	7.37	0.86	0.69	0.03	2.01	10.00	7.13	3.53	9.38
Mt. Rainier-Jackson	49.11	8.44	9.32	0.43	0.00	2.11	4.24	10.00	7.13	3.53	3.90
Vancouver-Blairmont	49.82	8.44	7.97	0.83	0.00	1.68	3.11	6.76	5.74	7.50	7.79
Anacortes-202 Ave.	55.68	6.52	7.46	0.00	4.48	5.00	4.81	10.00	7.13	3.53	6.75
North Bend	58.38	8.59	7.97	2.48	3.91	0.26	5.00	10.00	7.13	3.53	9.51
Kennewick	60.58	10.00	10.00	10.00	8.28	0.00	0.00	0.61	10.00	10.00	1.70
Enumclaw-Mud Mountain	71.40	9.92	9.66	7.54	10.00	1.25	4.41	10.00	7.13	3.53	7.95

Ozone: 8-Hour Design Values

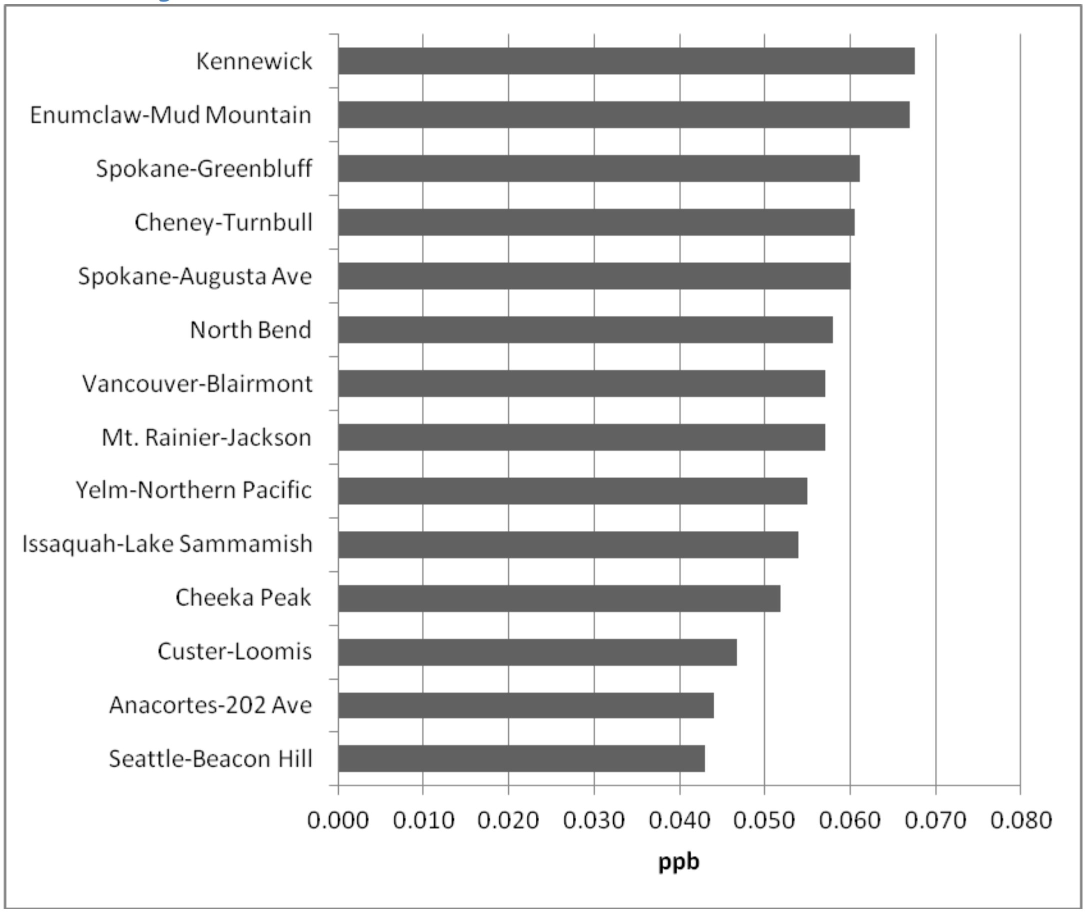


Figure 39. Ozone decision matrix: design values

Ozone: 75th Percentile D8M

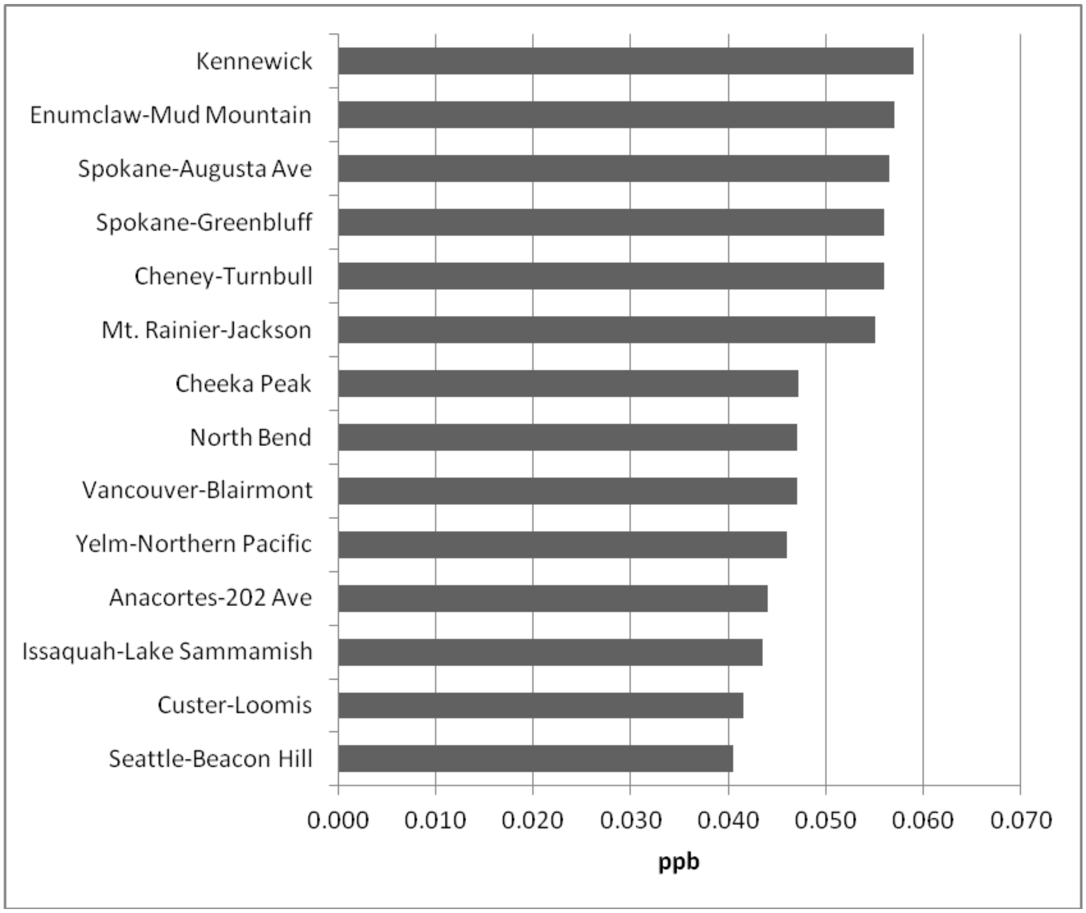


Figure 40. Ozone decision matrix: 75th percentiles

Ozone: Days over 65 ppb

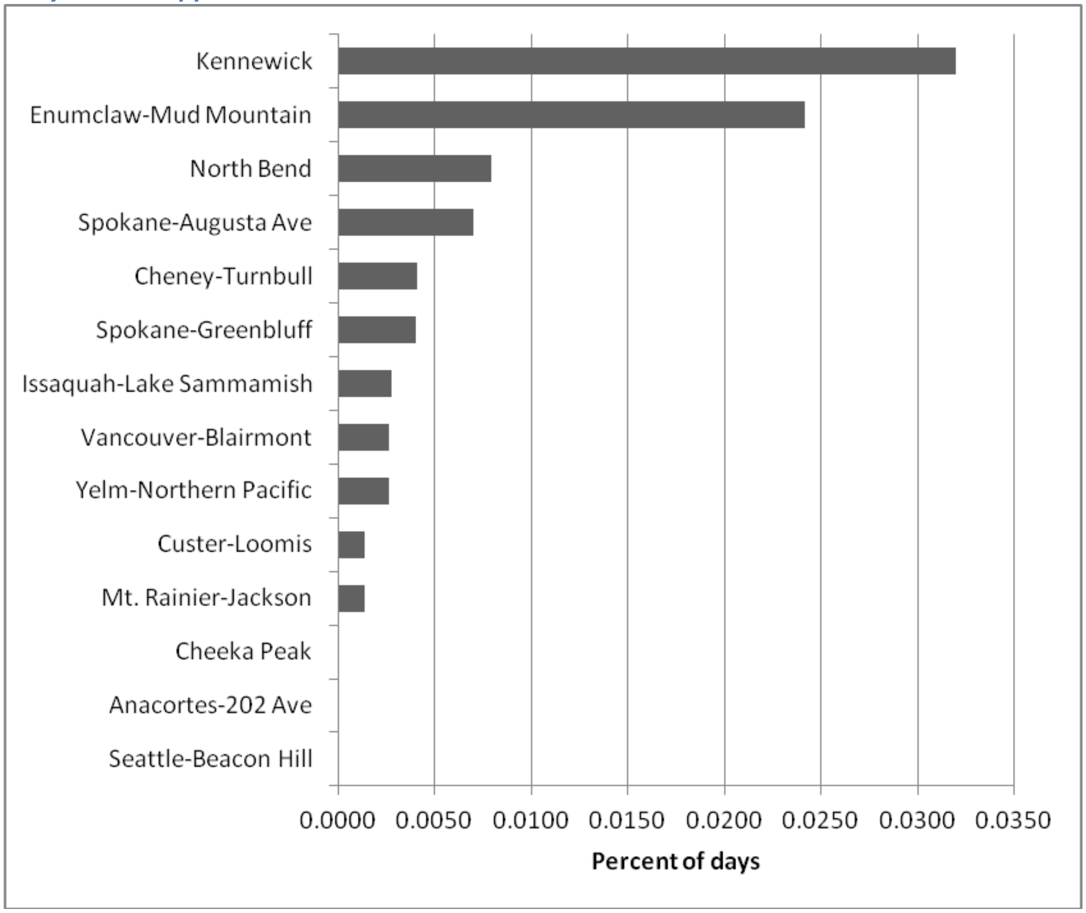


Figure 41. Ozone decision matrix: percent of days over 65

Ozone: Probability of a Single Day over 70 ppb

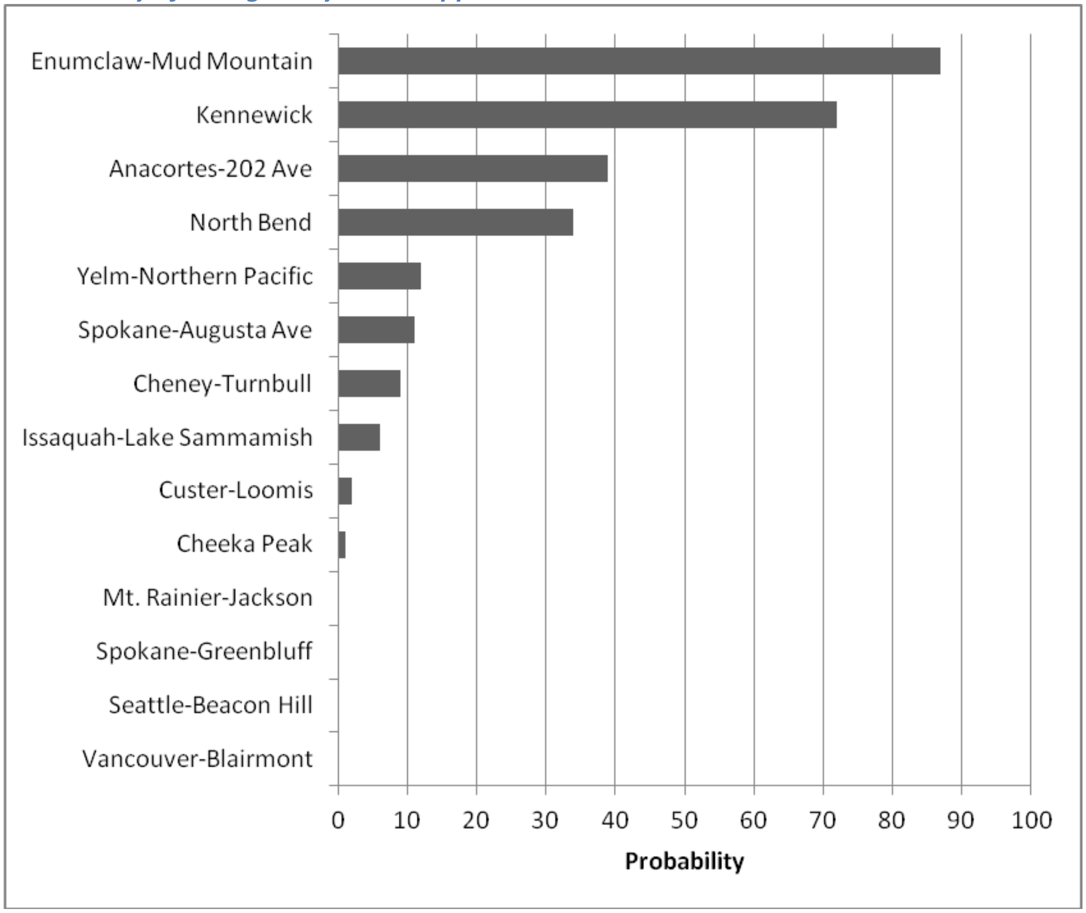


Figure 42. Ozone decision matrix: probability of a day over 70 ppb

Ozone: Trend in 98th/75th Percentiles

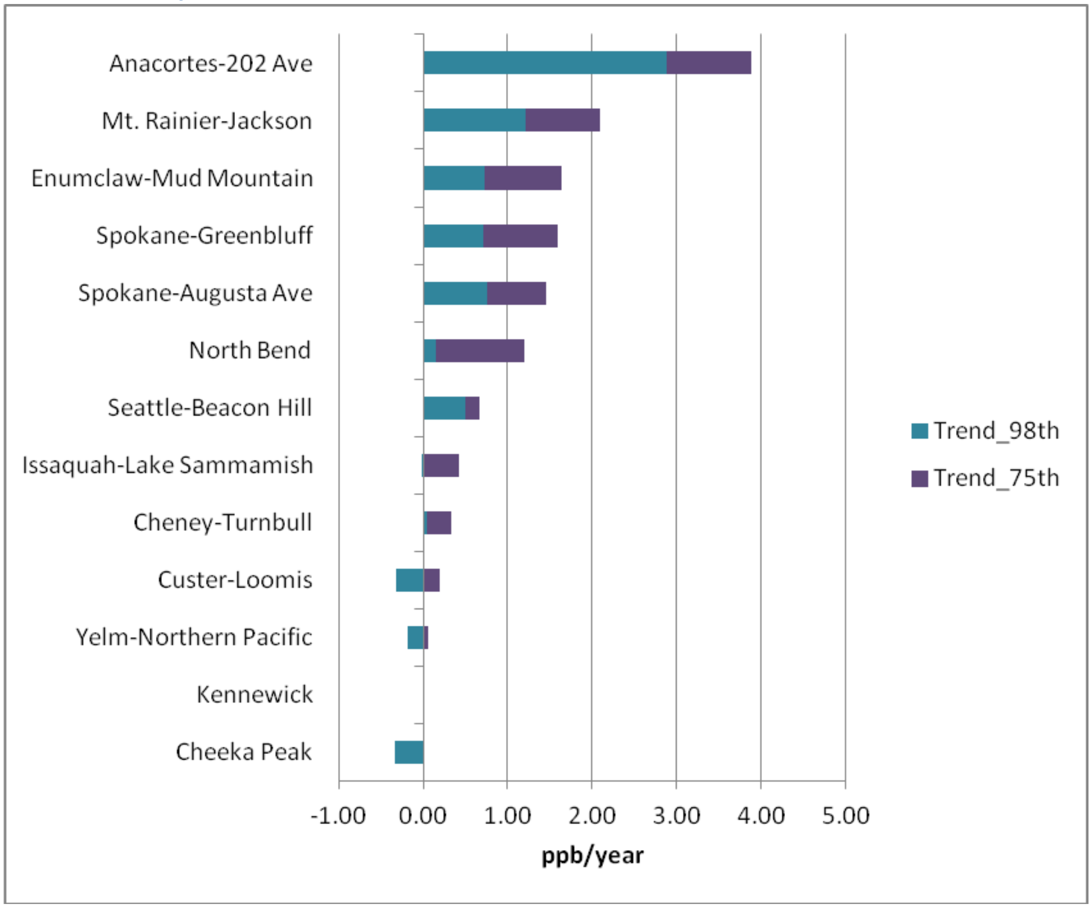


Figure 43. Ozone decision matrix: 98th and 75th percentile trends

Ozone: Population of CBSA

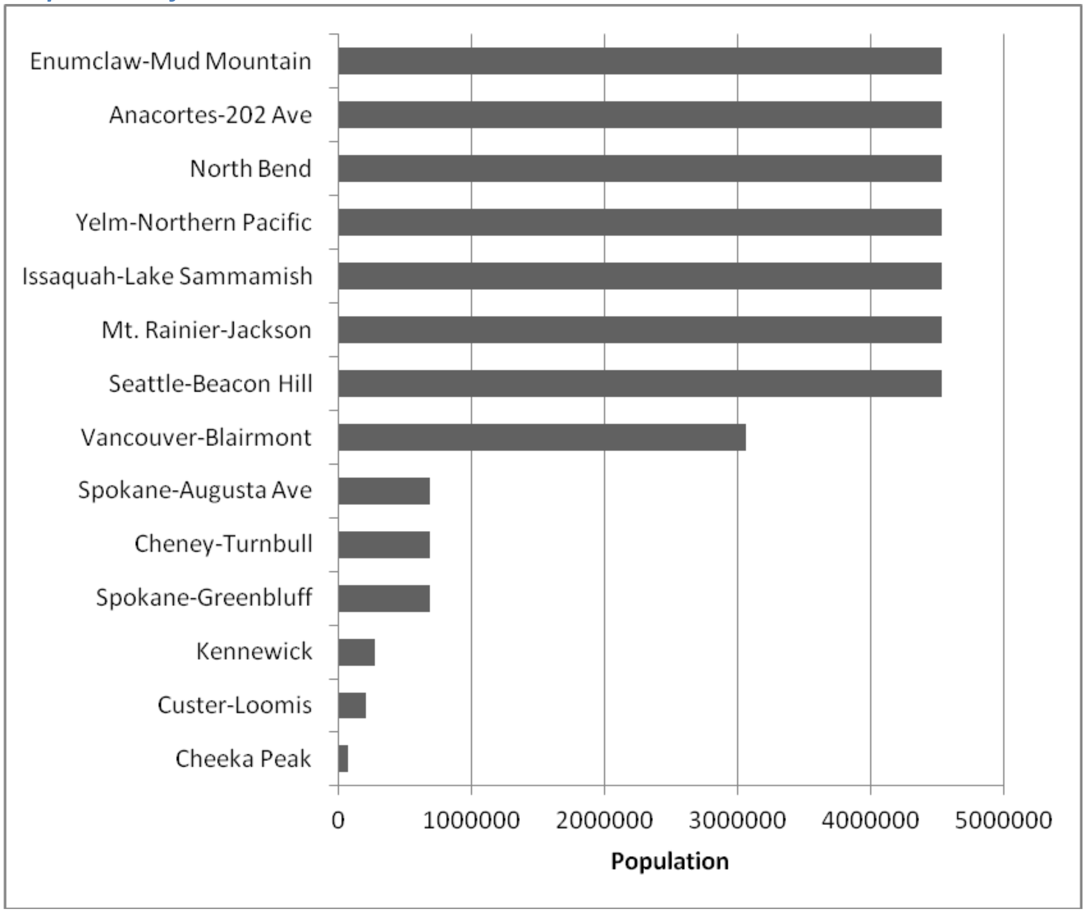


Figure 44. Ozone decision matrix: population of CBSA

Ozone: Population Growth in CBSA

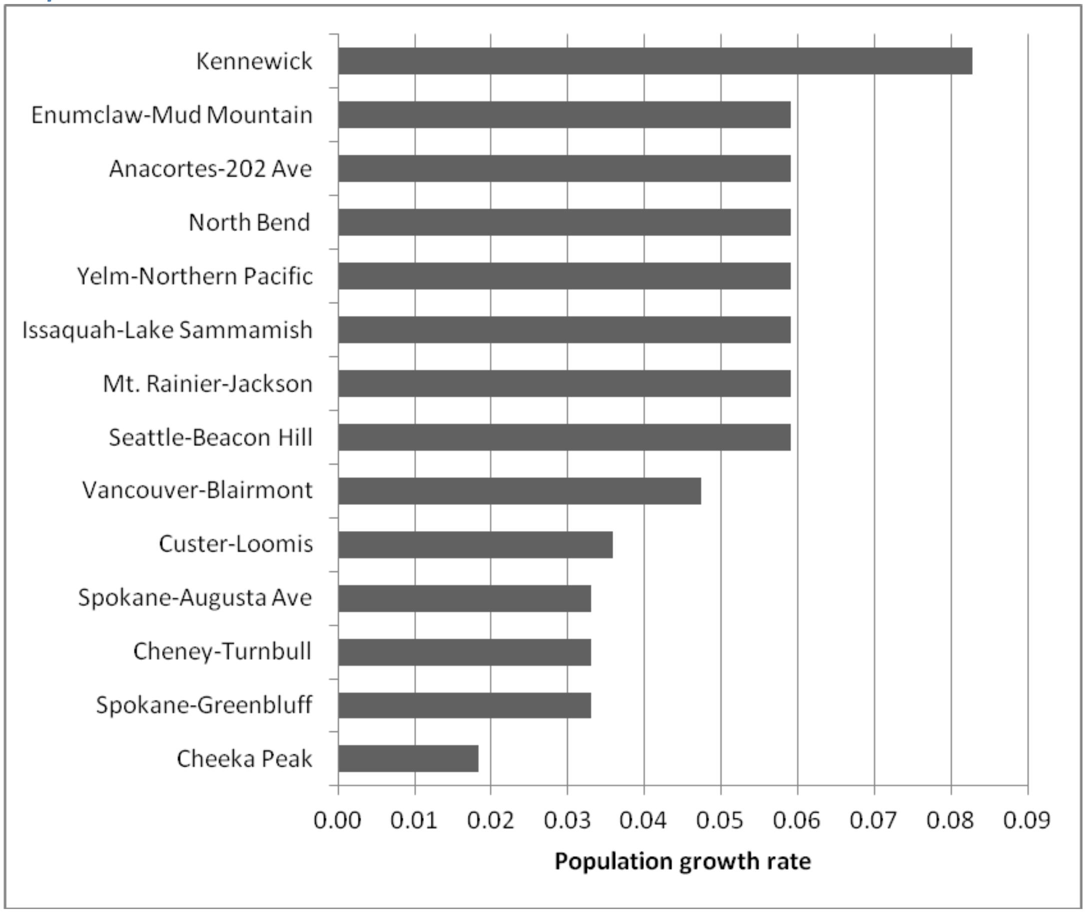


Figure 45. Ozone decision matrix: population growth

Ozone: Environmental Justice Index in CBSA

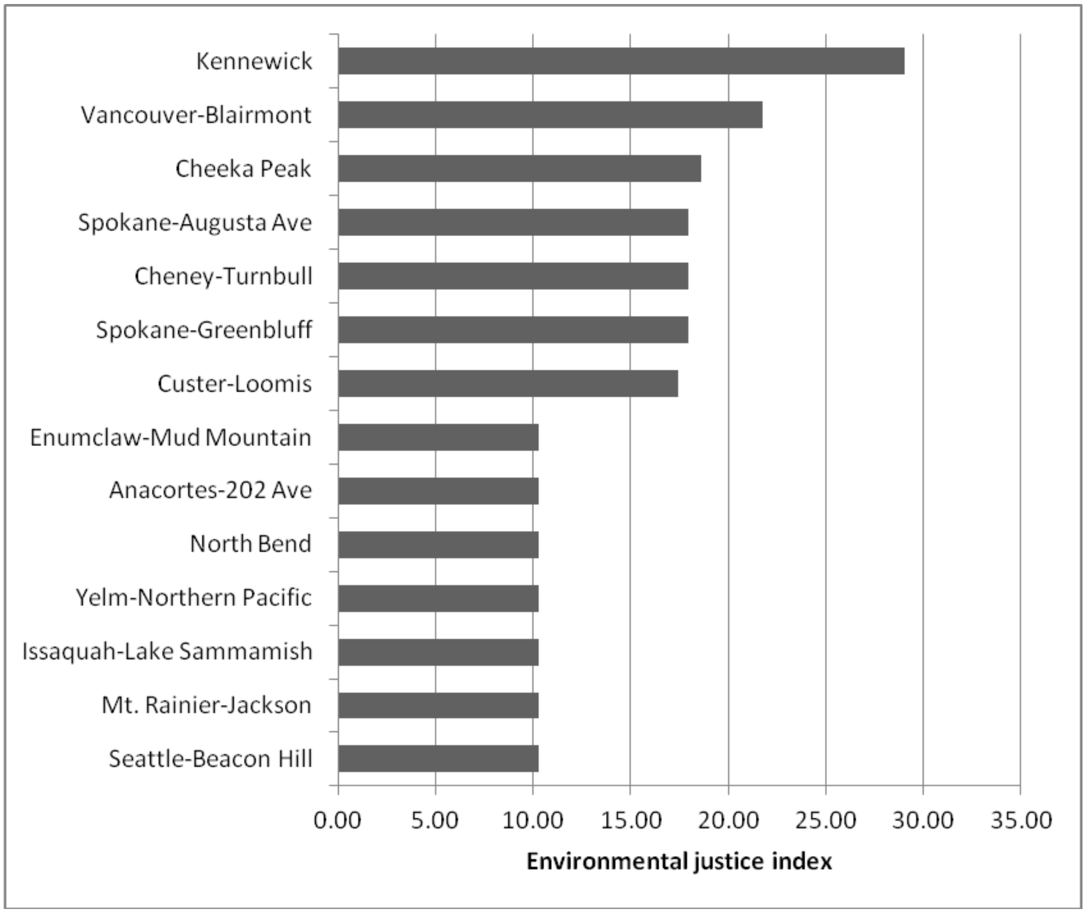


Figure 46. Ozone decision matrix: environmental justice index

Ozone: AIRPACT Model/Monitor Error

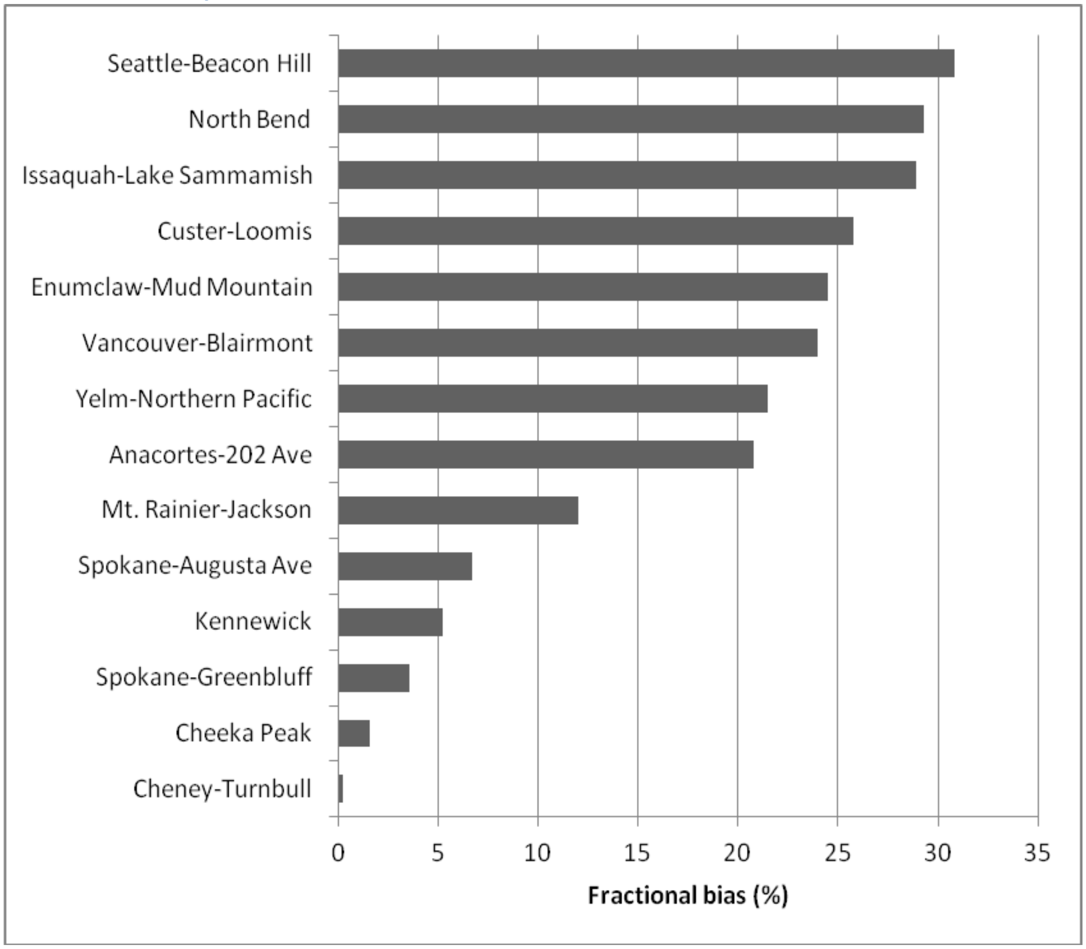


Figure 47. Ozone decision matrix: AIRPACT model/monitor error